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PREFACE

The First Canadian Conference on Urban Infrastructure brought together many of the people participating in the struggle to maintain Canadian cities as the hallmark of urban environmental quality. Included were political, managerial, and technical leaders of many of Canada's urban communities, representatives of federal and provincial governments, consultants, contractors, and academics. Several recent studies have indicated a serious deterioration of roadways, water systems, stormwater control facilities, public building, bridges, and wastewater management systems. This deterioration affects the economic well-being of Canada. People, the cities they live in, and the industries they work at and rely on for products, are all affected by the performance of various components of municipal infrastructure.

This conference is a follow up to the work of the Federation of Canadian Municipalities as reported in "Municipal Infrastructure in Canada: Physical Condition and Funding Adequacy," June, 1984.

An underlying theme, which becomes evident when examining this document, is that the urban area planning process must allow for operation, maintenance, and renewal activities.

The format of the proceedings follows the actual program of the conference. Minor rearrangements have been made where necessary for the continuity of the document.

Daniel W. Smith
Gary W. Heinke
James W. Knight

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STATE OF URBAN INFRASTRUCTURE IN CANADA

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ABSTRACT

In 1984, the Federation of Canadian Municipalities established a Task Force on infrastructure and funding for a Technical Committee to review the physical condition and funding adequacy of Canada's urban infrastructure. This paper reviews the Technical Committee's findings, the recommendations adopted by the Federation to solve the problem, and the progress and problems that have been encountered in the effort to implement the committee's recommendations. Variations in interest, approach, and degree of success in different parts of Canada, and with respect to the different levels of government are examined. The City of Vancouver is used as a case study to illustrate some of the problems being encountered and methods of dealing with them.

RÉSUMÉ

En 1984, la Fédération canadienne des municipalités a constitué le groupe d'étude sur l'infrastructure municipale et mis de côté les fonds nécessaires aux activités d'un comité technique chargé d'examiner l'état physique des infrastructures urbaines du Canada et de voir si les fonds affectés à l'infrastructure des municipalités canadiennes sont suffisants. L'exposé donne un aperçu des conclusions de ce comité technique et des recommandations adoptées par la Fédération pour résoudre le problème, ainsi que des progrès accomplis et des problèmes survenus au moment de mettre ces recommandations en pratique. Il fait état des divers degrés d'intérêt manifesté dans les différentes régions du Canada et par les différents ordres de gouvernement, ainsi que de la méthode employée pour concrétiser les recommandations et de la réussite obtenue. Se servant de la ville de Vancouver comme exemple, l'auteur illustre certains des problèmes qui surviennent et les moyens possibles de les régler.

INTRODUCTION

In 1984, the Federation of Canadian Municipalities (FCM) carried out a survey (1) and study of the infrastructure problem in Canadian urban areas. A large number of responses from officials across Canada formed the basis for an assessment of the problem. The appendix of this paper contains the conclusions and recommendations of that study. Very briefly, these identify the problem of a rising backlog of necessary infrastructure rebuilding, estimate costs to bring infrastructure back to acceptable levels, suggest intergovernmental co-operation to raise necessary additional funding, outline steps which would reduce costs and improve efficiency, suggest a review of priorities, and call for steps to increase public awareness of the problem.

This paper highlights some of the major findings of the FCM study, but since most participants in this conference are probably familar with the study, the focus of this paper is on what has happened since the FCM adopted the recommendations, progress to date in the various parts of Canada, and problems being encountered in carrying out the recommendations. The paper also offers some suggestions on how the obstacles being encountered can be overcome and what the next steps should be in solving the urban infrastructure problem.

WHICH PUBLIC FACILITIES REQUIRE ATTENTION?

In reviewing the condition of existing urban infrastructure, similar results have been obtained from surveys and studies in Europe and North America. It is clear that throughout the western world a backlog of necessary rebuilding has grown to unacceptable levels. Generally, the facilities which are in the greatest need of attention are roads, bridges, sidewalks; then sewer collection systems and water distribution systems. In Canada, about 70% of respondents to the FCM survey identified roads and bridges as being the facilities in the worst condition. Subsequent studies, such as the Union of British Columbia Municipalities' survey (2) smaller B.C. municipalities, have reaffirmed these conclusions. Other public facilities, such as parks, recreational facilities, community centres and daycare centres, have been found to be generally in better condition; most communities report the situation as being acceptable. In looking after infrastructure, clearly there has been a shift in emphasis from the basic, non-glamorous needs to other, real, but less fundamental, needs. It is also true that some facilities, such as daycare centres, are in good condition because they are relatively new. Municipal governments did not provide these at all in the first half of the century.

COSTS OF CORRECTION

In Canada, the FCM studies estimated that the cost to restore existing facilities to reasonable levels is about $12 billion (1984$). This is a cost of about $700 per person on average and, when looked at in terms of municipal budgets, represents a 25% increase in public works budgets or a 7% increase in total municipal budgets for a period of 10 years. This assumes the continuation of virtually no contributions from the federal government and limited contributions from provincial governments. Since then, the FCM has suggested a 1/3-1/3-1/3 sharing of this funding requirement and, should that occur, municipal costs would go down dramatically, perhaps to a 2 to 3% increase in budgets. Even if senior government shares were only half of that amount - one sixth of a share in the costs - the remaining local government share would be achievable in most cases.

CAN COSTS BE REDUCED?

Costs cannot be reduced to the extent that additional funding is no longer required. The FCM study and subsequent work has shown, however, that to some extent, costs can be reduced and other sources of revenue found as outlined below.

Resistance to Public Pressure

First, public taste for elaborate and expensive facility treatments, which has grown in the past 15 years, makes infrastructure renewal more costly. The ability of the public to press for such treatments, through greatly increased public participation, has contributed to these costs. Without eliminating public involvement, it is possible to resist these pressures and thereby reduce cost of renewal.

Prompt Correction of Problems

Elimination of delays in correcting problems can also reduce costs. For example, where a standard roadway has deteriorated and must be replaced and the community demands a gold-plated, attractive treatment far in excess of the standard throughout the rest of the area, considerable delay can occur (often 2 years or more). By the time the work is finally undertaken, deterioration has advanced to such a degree that complete rebuilding is necessary, rather than the less expensive correction. It is necessary not to let expectations build up for elaborate works until the general renewal of all facilities has been completed, at least to standard levels of treatment. Cost savings are possible in this way.

Technical Efficiency Improvements

It is possible to reduce costs through technical efficiency improvements. Generally, these are associated with standardized treatment and automated mass production techniques. Much was done in this connection during the past two decades, and opportunities for further cost savings in this direction are limited, but possible.

Payment by Users

Finally, there is room for greater reliance on payment by users, and other approaches of this sort are possible and have been described in technical reports (3) available on this subject. Some have been successfully used in the U.S.A. Although total cost is unchanged, these devices can reduce direct government costs, and the FCM study supports their increased use.

All of these techniques can be used to assist with the cost problem, but they alone will not be enough. Even if all of the cost-cutting techniques could be achieved, additional funding from other levels of government still would be needed to solve the problem. This additional funding must be found by all levels of government and that is one of the major recommendations of the FCM study.

FACTORS DETRIMENTAL TO RESOLUTION OF THE PROBLEM

All levels of government have reacted to the FCM studies, and there is a genuine effort to address the problem, particulary at the local government level. Generally, the recommendations are not being implemented and progress is very slow. Many of the original causes of the problem remain. They and other obstacles being encountered are working against a solution of the problem in a reasonable time frame. Several general classes of obstacles must be overcome to solve the problem including greater awareness of the problem and more co-operation among governments.

Lack of Awareness of the Problem

Before any problem can be solved, we must be fully aware that it exists and understand it reasonably well. Although public awareness has been increased a great deal, the public's understanding of the problem is still far from perfect.

One factor which contributes to the problem is that public works facilities, once installed, tend to be taken for granted and forgotten, understandably so since many of them are underground and out of sight. There is little political glamour associated with their renewal. The tendency to favour new works over rebuilding remains at all levels of government.

Another obstacle is the tendency by some to view the infrastructure problem as incomprehensible and unsolvable. The result is that many, who could do more, leave the problem for later consideration. In fact, if action is taken reasonably soon, the problem would be manageable by the three levels of government. With cooperation, it should be possible over a reasonable period of time to cope with the rebuilding of infrastructure without unreasonable budget increases. The sooner we begin to address the problem, the easier it will be to cope with it.

Others tend to view the problem at the other extreme of the alarm spectrum. Judging from press coverage in some areas, the situation is catastrophic. Bridges are collapsing, people are being killed, and water systems are flooding large parts of cities. In reality, throughout the western world, the situation is not catastrophic. Rather, a slow, creeping neglect has occurred over a long time and could continue for a while yet. Granted, there are examples in Canadian urban areas, Winnipeg for example, where water systems have reached a state where the number of breaks per day is at an unacceptable level. In Vancouver, recently, a break in a major old watermain necessitated the boiling of water in the entire city. In other areas, some bridges are no longer usable. By and large, however, the deterioration is more subtle, but very wide-spread. A few municipalities have already reached the point where all known funding systems are inadequate to cope with the problem. Should the situation be permitted to continue, many more municipalities could face this dilemma and then the problem could become unmanageable. This point has not been reached - yet.

Municipal officials tend to say, "We don't really have as bad a problem here. I was just in such and such a city, and they are in far worse shape". This type of attitude is a significant obstacle to renewing the infrastructure. Certainly, one can always find some other city that is worse off, but this does not deal with the fact that a backlog of necessary work is building up in your own city.

The following case study in Vancouver illustrates this problem. It has been found that infrastructure needs overall in Vancouver are not as great as the average need in Canada. In fact, needed expenditures per capita are only about two-thirds those of the average Canadian city. Some have interpreted this to mean Vancouver has no problem and need not have any special programs.

Economic Difficulties and Lack of Co-operation Between Governments

During the past decade, inflation and interest rates were so high that there was extreme reluctance to borrow money. Many Directors of Finance pushed the concept of "pay-as-you-go". This meant financing all works from direct revenue in the form of mill rate increases and not borrowing at all. It was a concept comparable to totally eliminating mortgages for homes and, of course, proved unworkable and failed. Unfortunately, even though interest rates and inflation are now considerably lower, similar pressures continue. A newspaper from a major Canadian city recently expounded the virtues of pay-as-you-go and proposed the virtual elimination of all borrowing. Although debt must not be permitted to grow unreasonably, borrowing has always has been and must always remain a reasonable part of our municipalities' funding structure. Otherwise, infrastructure problems will never be solved.

A contributing factor to the infrastructure problem was the termination, by both the federal and provincial governments throughout Canada, of assistance programs such as winter works, capital programs, employment programs, and provincial revenue-sharing programs. Although the condition of urban infrastructure always has been primarily the responsibility of municipal governments, the assistance of senior governments has been significant, contributing perhaps up to 25% of the cost of new facilities. This left more money for infrastructure maintenance and rebuilding by the municipal governments.

Today, existing large deficits are obviously a very real concern to the federal and provincial governments, and consequently these governments, for fear of increasing their deficit, are reluctant to assume responsibility for rebuilding urban infrastructure facilities. However, studies (4) by the FCM and others have demonstrated that infrastructure renewal is a very labour-intensive endeavour and can significantly increase employment with positive spin-off effects for the national economy. Similarly, infrastructure renewal can directly improve the economic viability of commerce and industry, thereby generating increased national revenues which can reduce deficits just as effectively as restraint. The reluctance remains, however, and continued attention to this is required.

At the same time, local governments, in these continuing times of restraint, are tending to shift responsibility to the senior governments, because their limited revenue sources make it difficult for them to meet their responsibilities. There is some justification for this in that some senior governments virtually have terminated cost-sharing and grant arrangements. They should be re-instituted. For, even if the federal and provincial governments shared a third of the costs of all programs, funding increases at the municipal level still would be needed. Municipalities simply will have to bite the bullet and raise the necessary funds to stop the deterioration of our essential infrastructure.

Cooperation between the three levels of government in trying to solve the infrastructure problem is far from perfect. For example, federal and provincial departments of environment have created pollution control acts which make sewer treatment and discharge facilities, that were constructed long before their enactment, illegal. The Greater Vancouver Regional District was recently found to be in violation of federal and provincial acts and ordered to extend a sewer outfall to deep water immediately, at costs in excess of $50 million. Over 90% of this cost must be borne by the City of Vancouver, significantly diverting funds from other pressing infrastructure renewal needs. Even though the expenditure is a direct result of new senior government acts and requirements, senior governments have refused to share in the cost. If senior governments wish to raise the national level of environmental protection at this time, they should provide the necessary funding to do so. It is unreasonable to expect local government to assume these very large costs alone.

Recently, the federal government announced that it intends to strengthen pollution control legislation significantly. Strict enforcement, even of existing environmental legislation, could have a profound effect on local government costs which could aggravate the already serious infrastructure renewal problem. It is probably beyond the financial means of most municipalities to meet all the requirements of environmental acts right now.

Other Obstacles

Shift in Priorities. There has been a significant shift in priority from the provision and reconstruction of basic necessities, such as sewer and water systems, to recreational, cultural, and other needs which had been regarded as optional, or at least of lower priority, in former years. It seems this trend is continuing, and pressure from many sources exists for additional services at the municipal level that previously were non-existent or provided by senior governments. This, of course, makes it more difficult to stress sufficiently the financial needs for basic infrastructure renewal. Eventually, significant and increasingly visible deterioration of the infrastructure will, in itself, cause the public to shift its emphasis back to basic infrastructure renewal. By that time, costs will be much higher and the backlog much less manageable. We should not permit things to deteriorate that far before dealing with the problem.

Development of Standards and Cost Benefit Criteria. Another obstacle being experienced throughout the western world is the desire by some authorities to develop standards and cost benefit criteria which would result in absolutely equitable and standardized treatments throughout a nation. The FCM study recommended that work begin on standardization, and this is a logical and generally desirable long-term objective, but one which will require a great deal of time. The rebuilding of our infrastructure simply cannot wait that long. Furthermore, it will not be possible to create realistic standards and priority criteria which will be completely, universally applicable. There exists a legitimate variation in acceptable service levels across Canada. Road and sidewalk service levels in Toronto can understandably be significantly different from those in Yellowknife, and some of this difference legitimately may be the result of local preference, as well as vastly different population densities and volumes. If we are not careful, the quest for standards could seriously delay resolution of the infrastructure problem.

A Stitch in Time...

The obstacles to the solution of the infrastructure problem are understandable and part of our nature. They must be overcome, nevertheless, and the sooner this happens, the easier it will be to cope with the problem. Continued delay will not make the problem disappear and, in fact, will permit deterioration to advance to the point where costs will be much higher. "A stitch in time saves nine" is certainly appropriate for this situation.

PROGRESS TO DATE

Having reviewed many of the reasons for slow progress, I should point out that some progress is being made. The following sections present an outline of this.

The infrastructure problem was recognized in the United States several years before it was in Canada. Accordingly, they are ahead in their attempt to deal with the problem. Although Canada's solutions may not parallel the American approach exactly, it is useful to review their progress, as it may give us some insight into what lies ahead.

Progress in the United States

a) The problem first was identified (1980-1983) in "needs" studies such as the American Public Works Association's "Revenue Shortfall" (5) and the National League of Cities' study, "Infrastructure: An Initial Assessment" (6). The main purpose of these studies was to create public awareness of the problem and to bring it to the attention of senior governments.

b) Senior governments then carried out their own studies; e.g., those of the Congressional Budget Office and the Joint Economic Committee of Congress. These resulted in the passing of such legislation as the Public Works Improvement Act of 1984.

c) Under the Act, the National Council on Public Works Improvement was created, which is currently reviewing the nation's infrastructure problem and published its first report (7) in 1986. The Council will recommend action to the President and Congress when it has completed this work.

Although an infrastructure act exists in the United States, no federal funding mechanisms have been set up. They are still being studied. In terms of physical works and provision of funding, at the federal level in the United States, expenditures on highways and roads increased by 58% between 1982 and 1986, mostly due to a $0.05 gasoline tax increase. With regard to other forms of infrastructure, the latest information (7) shows a steadily decreasing federal input toward public works grants and similar programs.

Progress at state and local levels has been more significant. States such as Washington, California, New Jersey, Connecticut, Oregon, and Georgia have created a number of authorities to deal with infrastructure. In some cases, trust funds have been set up which provide low-interest loans for local public works projects. In Washington, for example, approximately $20 million per year now is available for this purpose. Although there has been an ongoing shift of responsibility from the federal to the state and local levels, federal assistance was never curtailed in the United States to the degree that it was in Canada, where it was essentially terminated.

At the local level, U.S. urban areas have instituted new revenue techniques such as user charges for streets, so that they could start coping with the infrastructure problem. Examples are Bellevue, Washington; Pocatello, Idaho; and Fort Collins, Colorado.

Comparable Progress in Canada

The Federation of Canadian Municipalities' 1984 infrastructure study is comparable to the first-generation studies ((a) above) in the U. S. There have been subsequent studies refining the needs of various provinces and cities in Canada. No senior government studies comparable to those listed in (b) and (c) above, which would be aimed at direct senior government legislation, have been published in Canada, although the Department of Public Works has recently been making surveys which may be comparable. The FCM and several provincial governments have asked for Federal involvement, but this has not been achieved to the degree that it has in the U.S. There are no proposals for federal legislation comparable to the U.S. Public

Works Act. There is no federal gasoline tax earmarked for infrastructure renewal in Canada.

Federally. Discussions have been held in Canada between committees of FCM and federal departments such as Transport and Employment and Immigration. The purpose was to make existing funding in these departments more available for urban infrastructures. Some regulations have been altered to facilitate this, but a recent review of cities across Canada shows it is still extremely difficult to qualify for and use existing employment programs for infrastructure renewal because of complex regulations aimed at creating employment in target groups. Thus, little of the money available in federal employment programs is being used for infrastructure renewal. More cooperation is possible in this area and should be provided.

Provincially. At the provincial level, agreement was reached amongst provincial Ministers' of municipal affairs to support the essential elements of the FCM proposals on infrastructure and to bring these forward collectively to the federal government. Since FCM proposals are for equal sharing among the three levels of government, provincial support is a significant step towards funding resolution, particularly since provincial support is essential to convincing the federal government to participate.

Another major step that has occurred at the provincial level is the decision by the Province of Alberta to make its provincial capital grants available for infrastructure rebuilding as well as for new construction, which was previously the sole purpose. Cost-sharing under this program with Alberta's municipalities is 75% provincial and 25% local government. and significant funding is available for the programs. The province also has made changes in its "municipal partnership for local employment programs" to permit lower-interest loans to municipalities. More details on these programs will be given in other papers at this conference. For now, these changes can be considered similar in significance to those taking place at the state level in the U. S.

The Province of Ontario has just agreed to pay half the cost of municipal studies to halt deterioration of watermains and sewers. A fund of $2.5 million has been set aside for this. Ontario also is prepared to provide contributions for water and sewer rehabilitation and is currently attempting to get matching federal funds.

At the municipal level, the infrastructure problem has been recognized and a shift in priority and emphasis towards infrastructure renewal has occurred. In recent years, Ontario municipalities have been carrying out infrastructure works which exceed available provincial cost-sharing programs and necessitate expenditure of 100% local dollars. Regina has provided funding for "catch-up" works. Edmonton has had a significant shift in emphasis towards infrastructure renewal, partly assisted by the current economic conditions which work against new construction. Vancouver has had a successful plebiscite specifically for infrastructure renewal on the condition that federal and provincial cost-sharing materializes.

In summary, progress towards infrastructure renewal in Canada has been greatest at the local level. There is general support at the provincial level with one province having programs in place which compare favourably with U.S. states. Several other provinces have improved their programs also. At all levels of government, especially the federal level, progress is behind that in the United States. Not only is there need to do more at each level of government, but more work is necessary to establish a coordinated approach to solving the problem involving all levels of government.

SUMMARY

The infrastructure problem in Canada is not catastrophic, but it is very significant. It must be dealt with soon, or deterioration and backlogs will grow to the point where many municipalities will be unable to cope with the funding needs. That is how people and cities go broke slowly. Costs are manageable if all levels of government share them. In fact, if the problem is addressed soon, and with general cooperation, cost increases over current expenditure levels will not be that large.

These necessary works are labour-intensive and can reduce unemployment, thereby giving a boost to the economy. Infrastructure renewal can also improve the competitiveness of business and industry, thereby creating economic activity and additional government revenues. To reduce costs, our priorities need to be reassessed and the more fundamental needs stressed over those that are desirable, but less essential. Also, waste has to be eliminated or at least reduced by making it clear to the urban public that extravagant and inconsistent treatments just are not affordable. More rapid and consistent decision-making by government would assist as well. There is also a need for legislation similar to that in the United States for dealing with funding for infrastructure correction on national, consistent, and rational basis. Of course, this is difficult to achieve at times when huge government deficits have built up, and while every attempt is being made to reduce these. However, deficits can also be reduced by revenue increases resulting from infrastructure renewal.

Most of all, the problem needs the coordinated attention of the federal, provincial, and municipal governments.

Can we solve this problem? Certainly; if we work together. But that's the hard part - working together.

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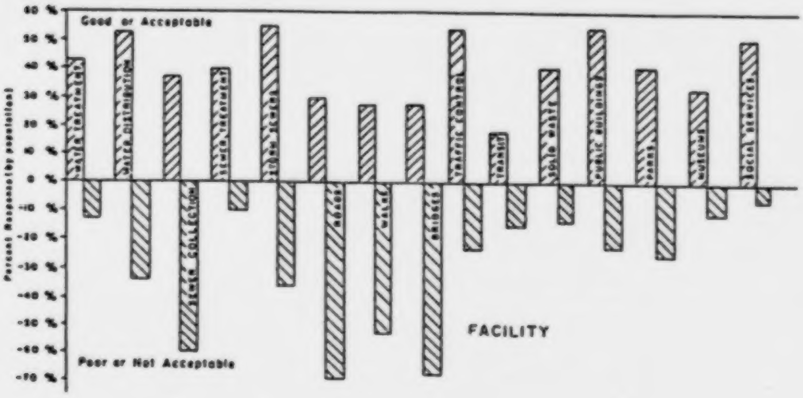
APPENDIX A

CONDITION OF CANADIAN URBAN INFRASTRUCTURE

The majority of survey responses indicate that an infrastructure problem exists in Canadian urban areas. This supports the conclusions of the mayors' pre-survey. Different types of infrastructure are in different states of adequacy. This is illustrated below.



As with the mayors' pre-survey, roads are identified as being in the greatest need of attention by 70% of respondents. Sidewalks, bridges, and sanitary sewage collection systems are also identified as problem areas by the majority of respondents. More than half of respondents think that public buildings, water distribution sytems, traffic control facilities, and storm sewer systems are in good or acceptable condition. Most respondents think that parks, solid waste facilities, water treatment systems, and such social service facilities as day-care centres are in good or acceptable condition. It should be noted that the above diagram pertains to the condition of existing facilities. The survey did not attempt to determine whether there was a need for more roads or more social service facilities.

APPENDIX B

CONCLUSIONS AND RECOMMENDATIONS OF THE FCM

1. A significant decline has occurred in the condition of infrastructure in Canadian urban areas. Steps should be taken to halt that trend.

2. The costs to bring the most seriously deteriorated forms of infrastructure (sewer, water, road and bridge systems) back to acceptable levels are high. Even when spread over a 10 year recovery period, these costs will represent an increase in current public works budgets of about 25%.

3. Additional local government funding sources should be found to help solve the revenue shortfall problem.

4. To raise the required funding is beyond the ability of many local governments and some assistance from other levels of government is required.

5. Better information systems should be developed, particularly in smaller municipalities, to permit better management of infrastructure systems and more effective use of available funding. Lack of information was a frequent reason given for not completing the survey questionnaire.

6. Greater interchange of information between Canadian municipal officials should be achieved through strengthened national associations and the publication of manuals on management practices.

7. To achieve a greater degree of national consistency in levels of infrastructure service, work should begin on the setting of service standards. This should be done in concert with the U.S. and European countries that currently are working on these. This is a long term effort and rebuilding of infrastructure should not await its completion.

8. Methods should be investigated which would reduce waste and excess costs due to delays and other impediments to reconstruction and maintenance of infrastructure.

9. Without jeopardizing the provision of new facilities needed to meet growth, a greater emphasis should be placed on maintenance and reconstruction as

opposed to new construction, especially in federal programs which might be developed in the future. This would extend the life of existing facilities.

10. Local governments should re-examine priorities so that the most essential basic services are emphasized during times of severe restraint. If this is not done, the economic health of our urban areas may be jeopardized and, with it, the other services as well.

11. Policies should be set by the FCM which could form the foundation and guidelines for recovery. The FCM should direct its Task Force on Urban Infrastructure, through its Technical Committee, to outline specific policies.

12. Programs should be established to begin implementing these policies and to deal with the reconstruction of the deteriorated forms of infrastructure over the next decade.

13. An intergovernmental partnership should be established which would bring the combined and cooperative efforts of the three levels of government to the solution of the infrastructure problem. The opportunity exists to reconstruct our urban infrastructure, to make our urban areas more competitive, to strengthen Canada's economic recovery and, at the same time, to employ large numbers of Canadians in these labour intensive works.

14. National priorities may need adjustment to recognize that Canada is becoming an increasingly urbanized nation. It is in our urban areas that most Canadians live and it is here that our greatest problems are developing.

15. Public awareness of the infrastructure problem should be increased to obtain public support for necessary remedial measures through the wide dissemination of this report and other means available to the FCM.

16. The FCM should direct its Task Force, through its Technical Committee, to proceed with Phase II of this study in order to crystallize policies and outline programs necessary for corrective action in cooperation with other levels of government where necessary.

17. Estimated costs of Phase II are $50,000. Funding should be provided for this purpose.

URBAN INFRASTRUCTURE RENEWAL:
THE U.S. EXPERIENCE

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ABSTRACT

The condition of the public works infrastructure in the United States has been a matter of much public debate and growing concern. The Congress of the United States has funded a 3-year study of infrastructure needs which is being conducted by the National Council on Public Works Improvement.

The Council, because of the limited time and funds available to it, is concentrating its efforts on basic and underlying issues. Although funding issues are not being ignored, other issues such as management needs, capital improvement program coordination and improvement, potential technological improvements and breakthroughs, and the relationship of public works facilities to economic development are being considered in depth.

RÉSUMÉ

L'état de l'infrastructure des travaux publics aux États-Unis fait l'objet de beaucoup de débats et est source de préoccupations croissantes. Le Congrès américain a commandité une éude de trois ans sur les besoins en infrastructure, étude qui est menée par le National Council on Public Works Improvement ou Conseil national d'amélioration des travaux publics.

En raison des délais fixés et des contraintes financières auxquelles il est assujetti, le conseil concentre ses efforts sur les questions élémentaires sous-jacentes. Bien que les questions de financement ne sont pas laissées pour compte, on s'attache surtout à des sujets comme les besoins de gestion, la coordination et l'efficacité des programmes d'amélioration des immobilisations, les perfectionnements et percées technologiques possibles et les liens entre les installations des travaux publics et le développement économique.

INTRODUCTION

A perception of basic need for public works infrastructure repair and replacement has developed in the United States over the past several years. The popular national press has highlighted the perceived deterioration of facilities, particularly streets, highways, bridges, and dams. So called "needs studies" have been conducted at various levels of detail in an attempt to prove that there is an immediate national problem which must be solved.

The Urban Institute has conducted a series of studies (1,2,3,4) of individual public agencies detailing their infrastructure maintenance and rehabilitation approaches for several key infrastructure areas. It was found that even within the same agency, the perceived condition of major infrastructure elements often were rated significantly differently and major rehabilitation strategies often would not allow replacement within the reasonably expected life of the facility; for example, rebuilding of streets, sewers, and water lines on a 200- to 500-year cycle.

The U.S. federal government over the past 20 years has implemented a variety of financial assistance programs which have been available to local agencies for long-term or limited periods. Such assistance often has been used to help agencies to meet specific federal mandates. Providing the local matching share of construction funds generally has been found to distort local priorities.

The majority of the federal financial assistance programs either have been phased out or appear to be coming to an end. Included in this category are wastewater treatment, block grants for community development, and general revenue sharing. This change in the availability of funding has led to increased local governmental attention to the problem of the overall condition of public works infrastructure and to the formation of a national study council to provide advice to the President and the Congress as to what should be done.

Figure 1 indicates the source of funds for projects. Less than one-third, 30.3%, were from general revenue.

For several infrastructure areas, national trust funds have been established to provide funding from dedicated sources of revenue. Prime among these have been funds for highways, airports, mass transit, and waterways. Although such trust funds were conceived as a means of assuring continuity, this has not necessarily been the case. In order to minimize overall federal spending and/or because of differences in legislative priorities, holds on distribution of accumulated funds from highways are currently in place due to lack of appropriate legislation.

Figure 2 indicates the use of the $14.1 billion fund in that year. Urban systems received only 5% of the available funds.

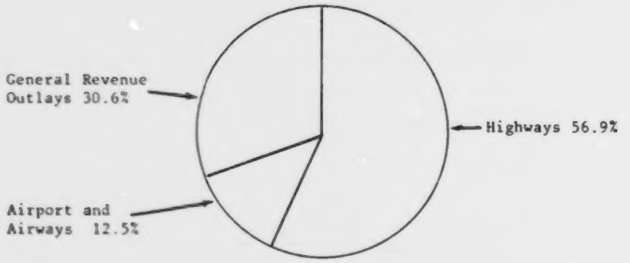


Figure 1. Revenue sources for federal public works, 1987
Source: Budget of the United States Government, 1987

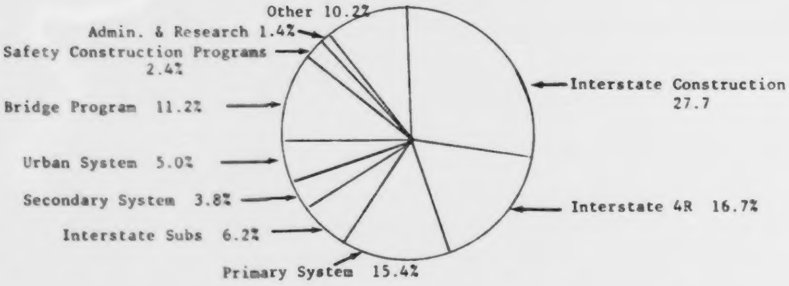


Figure 2. Highway Trust Fund Program Obligations by Activity(1985)
Source: Budget of the United States Government, 1987.

The National Council on Public Works Improvement was authorized by the Congress in 1984 and members were appointed by the President in 1986 in order that the Council could begin operation. The Council began its work by commissioning 32 reconnaissance studies of key issues. A report, "Defining the Issues," was issued in September 1986.(5) Two additional reports are to be prepared. The Council must submit its final report in the fall of 1988.

DEFINING NEEDS

A basic ingredient of any discussion of infrastructure requirements is a definition of the "total need." In the United States, as well as in Canada, "need studies" of limited classes of infrastructure facilities have been conducted for many years for a variety of reasons. The most common reason, it appears, has been to justify the need for new or augmented funding. Generally, the terms of reference have been set on a state or national basis and the question has often been posed as, "What resources would be required to provide 'x' level of service to your community?," or "What resources would be required to construct or rebuild to standard 'y'?"

The results of such studies have served to focus attention on problems, generally highlighting a discovered lack of funding, but have often obscured the potential solutions to the problems found by presenting such a large financial requirement that the task of providing funding for the total identified need appears insurmountable. In addition, it has been far easier to quantify "needs" in some portions of the public works infrastructure than others. For example, in the United States, many studies have highlighted the need for streets and highways. Such facilities can be readily inspected and judgments are made daily by the using public. The condition of underground pipelines, on the other hand, is not readily apparent. Likewise, where detailed engineering studies and inspection are required to determine a facility's condition, such as for dams and bridges, an agency's needs may not be readily available.

Examples of federal needs studies include the current estimate of $109 billion required by the year 2000 for wastewater treatment, even though $70 billion has been spent since 1972. Stormwater treatment and control needs are estimated to be between $500 billion and a trillion dollars during the same period.

Two sub-issues compound the difficulty of determining needs for local agency officials. The first is defining needs or level of service for many sectors of the public works infrastructure in response to local conditions. For example, what is the appropriate design storm for stormwater management systems for various population densities, or when should nationally-adopted standards for facilities be modified?

The second sub-issue is also very basic. Is there an inventory of facilities for which the individual agency is responsible and what is the "condition" of each element? At present, there are many agencies that do not have comprehensive inventories of the facilities for which they are responsible, nor are there defined standards for measuring the condition of some infrastructure items.

Recently, the governmental financial community has appeared to recognize the need for data concerning the capital investment of an agency when the overall financial condition of the agency is being evaluated. Thus, the need to improve a community's bond rating may act as the impetus for development of a comprehensive inventory and determination of what the total needs really are.

MANAGEMENT OF INFRASTRUCTURE

As emphasis in the public sector has shifted from the construction of new facilities to the maintenance of what is in place, the concept of managment systems for individual components has become accepted. For example, in the past ten years through the effort of both private consultants and the American Public Works Association, major advances have been made in the development and adoption of pavement management programs. Such systems develop a comprehensive inventory of the system and assign a physical condition rating to each segment. Utilizing economic concepts such as lifecycle costing and present value, managers can allocate their limited resources in the most cost-effective manner. Generally, such management decisions favor rehabilitation of facilities which are beginning to demonstrate deterioration, rather than those which have become seriously deteriorated.

The number of units that can be rehabilitated on a fixed budget when the facility essentially has not failed, is several times that which would be possible if the "worst" were fixed first. It has been shown that there are at least three distinct periods during the life of a particular infrastructure item: high service, declining service due to deterioration or obsolescence, and approaching failure. The first and third period may be rather lengthy, but the period of declining service may be relatively short. Thus, it is important to have techniques available to inspect and rate facilities during this critical period when rehabilitation action may be most cost-effective.

In contrast to systems for visible infrastructure such as streets and bridges, management systems for underground pipelines are still under development. Although individual utilities have developed systems for their own use, we have not yet progressed to common systems utilized by several agencies. Development of such systems, which have in effect been peer reviewed, will be a major step toward acceptance of maintenance management systems by additional agencies.

The American Public Works Association introduced its PAVER pavement management system in 1984 as a service to its members. Currently, over 70 agencies are utilizing the system and, with the recent introduction of a desk-top computer version, we believe that several hundred additional agencies will adopt the system.

TECHNOLOGY IMPROVEMENT

The relationship of advances in computer technology and hardware to improved management of infrastructure should not be overlooked. The sheer volume of data required to define our various systems and its condition is beyond the ability of most agencies to handle effectively. Compounding the problem has been the lack of priority within most agencies to provide mainframe computer service to line operations. Thus, the advent of the super, mini, and desk-top computers have at last made it possible to meet the data storage and processing needs of operating departments.

Technological improvements for most other areas of public works infrastructure are expected to be incremental improvements and no major breakthroughs are anticipated. In part, this is due to the nature of local government capital improvements where there is no reward and little incentive for risk taking by public officials and consulting engineers. The second reason is that there is relatively minor R & D taking place concerning the overall problems of systems other than roadways.

CAPITAL IMPROVEMENT PROGRAMS

There is widespread use of Capital Improvement Plans (CIP) by local governmental agencies in both the United States and Canada as shown by a 1980 study by the APWA(6). However, there is ample evidence (7,8) that relatively few agencies are utilizing such budgets effectively, and that the development of the CIP is not in accordance with generally accepted good practices. Use of a CIP by states is limited and the federal government does not prepare such a budget.

Characteristics which distinguish the best CIPs include:

- they are based on a comprehensive and accurate inventory of capital stock;
- they are integrated into the budget development process;
- they include realistic evaluations of the life-cycle operational and maintenance costs;

- they serve the needs of political officials as well as the bureaucracy;
- they provide for an evaluation of the relative benefits of alternative capital investment options, including rehabilition and replacement; and
- they are integrated with the land use and economic development plans of the area.

Surprisingly, there has been relatively little research done as to how CIPs are being used and how agencies may effectively utilize the CIP to guide economic development. There is a clear cut need to improve the CIP development process. It has been suggested that this can best be done only when the agency has developed its goals and objectives in order that improvment may be evaluated as to how well they fulfill the overall community development plan.

Another major concern with the CIP process is determining the tradeoffs and benefits of investment in one type of infrastructure facility vis-a-vis another. Currently, most allocation decisions are made within the context of the availability of funds for each individual system and cross issues are not addressed. Such fragmentation of decision making is encouraged by the current trend to form utilities for each infrastructure element or to form separate districts for the provision of the service. Generally, local agencies have not found satisfactory methods to integrate the process, although there are a few good examples of approaches which have been taken.

A major change in the CIP process which is being encouraged is the consolidation of the operating and the capital budget. The press continues to report about facilities which have been constructed which are beyond the financial capabilities of the owner to operate.

MANAGEMENT ISSUES

The APWA in 1970, and again in 1980, conducted a detailed study of local government public works agencies. In addition to detailing the extent of public works operations conducted by various departments and divisions, and the finances and extent of privatization, the studies reviewed the characteristics of age, experience, and education of key public works managers. The 1980 study found that key public works officials as a group were becoming better educated with college and advanced degrees. However, specialization in Civil Engineering, the generally accepted qualifying educational program, declined rapidly as compared to 1970, a decrease to 39% from the previously reported 50%. Key aides to the director of public works were found to have significantly reduced levels of education and engineering specialization in 1980 as compared to 1970.

The time in office and the number of years in public service of key public works officials has increased dramatically over the ten-year period. Likewise, the tenure and years of public service of key aides has also increased.

Thus, it may be concluded that if present trends continue, we may soon experience a major influx of younger public works officials and that these individuals increasingly will not have an engineering background.

The APWA has fostered a program of developing graduate management training programs for public works employees of public agencies for over 20 years. Such programs should become increasingly important to public agencies. Certainly the management of the public works infrastructure in the coming years will require a combination of engineering and management skills.

FEDERAL STANDARDS AND POLICIES

A major influence upon the decision making practices of local agencies has been the imposition of standards by higher levels of government. For example, during the past 15 years local agencies in the United States have been preoccupied with meeting sanitary sewage treatment standards of the federal or state governments. Available funds have been utilized to meet legal requirements established by the higher levels of government or the courts.

The disposal of solid and hazardous wastes is another good example. So many waste streams have become defined as hazardous, requiring that they be disposed of in specially licensed facilities, that widespread fraud and criminal intrusion in the field has become evident. The rapid change in the cost of disposal to various generators, along with widespread opposition to the siting of disposal facilities, has all but paralyzed operations in many areas of the nation. In the meantime, agencies are depleting the available disposal facilities and costs are escalating for all generators.

Presently, local agencies are faced with a federally-required urban stormwater discharge pollution abatement program, as well as more stringent standards for drinking water quality. As a rule, local agencies do not have any protection or assured financial assistance when standards or new requirements are imposed upon them. Several states have legislation that supposedly make state-funds available for implementation when such requirements or standards are imposed, but such provisions of law generally have been consistently ignored or circumvented.

The imposition of such standards has generally been without or with limited health-effect research to jusitify the specific standards promulgated. Rather, in many areas, standards have been set upon the ability to measure, or upon the efficiency of removal obtained in bench scale tests of new treatment processes.

For public agencies to catch up with their needs, a clear definition of the goals that they must achieve must be known, and there needs to be a reasonable determination that such goals will be adequate for a sufficient period of time to allow amortization of the useful life of the upgrading.

A second major policy area is that of public and private investment in public works infrastructure. The federal government for some years has promoted the concept of privatization of public facilities. The 1981 tax law changes, with their liberal rules for depreciation and issuing of tax-free bonds for economic development, stimulated the ability of the private sector to become involved in a variety of situations. However, the Tax Reform Act of 1986 apparently has made such investments very unattractive or impossible for the private sector. Even the principle of tax-free bonds issued by public agencies for governmental purposes may now be subject to a tax surcharge upon many investors; effectively increasing the interest rate which local governmental agencies must pay. The total loss to the federal government due to the use of tax-free bonds by local governments was $19 billion, of which only 45% was associated directly with bonds for public improvements.

PUBLIC WORKS INVESTMENT

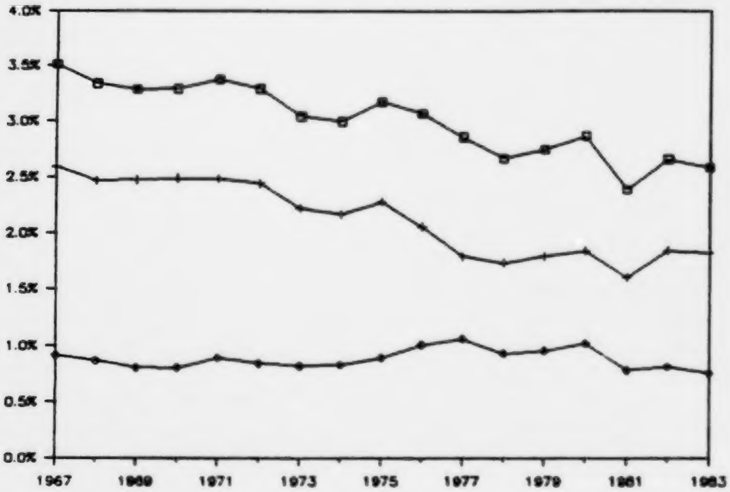
There is considerable evidence that the national investment in public works facilities has declined as a part of the gross national product during the past several years. For example, the percentage of GNP in 1967 was 3.5% and by 1983 it had declined to 2.7%. This trend was documented in a report for the Economic Development Administration (9) among others. Such a decline in investment as the nation continues to grow and existing infrastructure ages is alarming.

Although total governmental expenditures have not declined, there is a common perception that a greater share of the available resources is being utilized for social services.

Figure 3 shows the national trends which have taken place. Figure 4 highlights the rapid increase in spending for operation of facilities as contrasted to capital expenditures. In 1983 local governmental expenditures for operation and capital expenditures were estimated to be $64 billion.

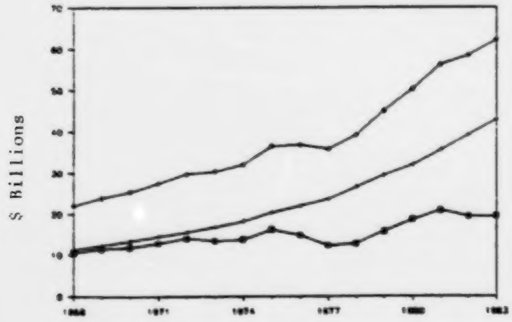
The current trade deficit, which has continued to grow even though national monetary policies, with the exception of the national debt, have been brought into line has caused attention to focus on productivity issues. Inherent to industrial productivity is the need for an adequate public works infrastructure. Transportation and environmental protection issues become paramount in any such analysis.

A new trend appears to be emerging for financing infrastructure needs. Revolving funds are being established by a number of states to allow expeditious



□ Total ✚ State & Local ◇ Federal

Fig. 3. Government investment in public works
As a percent of Gross National Product



● Total ● State & Local □ Capital

Fig 4. State and local infrastructure spending

Source: Congressional Budget Office, The Federal Budget for Public Works Infrastructure, July 1985.

funding of local needs. Amendments to the 1972 Clean Water Act, which were passed by the Congress in 1986, but vetoed by the President, called for federal financing of state revolving funds as a method by which the federal government could gracefully exit from the financing of wastewater treatment facilities.

Another concept which has been widely discussed involves turning back to the states the taxing power which has been used to support the various federal Trust Funds. However, local governments' distrust of states has made many officials leery of such turnbacks.

SUMMARY

After a long period of public hand wringing over the "Infrastructure Problem" and the development of a host of indicators of the seriousness of the problem, the United States has begun to take some effective steps to solve the "problem." Most encouraging has been the development of maintenance management systems for segments of the infrastructure. In addition, programs to standardize inventories of facilities and determine the condition of each element are being developed.

National attention is now being focused upon the delivery system for the preventive maintenance of the systems. Local capabilities and resources are being highlighted, rather than requesting the federal government to solve all of the problems. The solutions which are emerging will require improving the management capabilities of public works officials.

Experience of some local agencies with their implementation of pavement management programs suggests that the problems of local agencies may be solved with only slight total increases in resource allocation. Rather, improved preventive maintenance management programs and the use of newly available analytical tools has made it possible to improve street and road networks and reduce over time the amount of real resources required to provide the desired level of service. Development of required analytical techniques for other infrastructure elements will allow major advances to be made.

Financing of infrastructure needs continues as a major problem for local government agencies. Recent federal actions have exacerbated an already difficult situtation. As the total dimension of the problem which includes national tax problems, the federal debt, productivity, and responsibility for specific areas, is illuminated, I believe that we have an opportunity to develop a set of comprehensive policies that will lead to improvement and improved utilization of our limited resources.

Although as public works managers we believe that we are meeting the needs of the public and have enough experience to design and operate our capital stock adequately, perhaps at times we need to sit back and take a lesson from the public that we are trying to serve. Exhibit 1, Comment Concerning the Washington D.C. Subway System, is a case in point. The criticisms of the system, including the inability to double track the system, may all have valid design reasons, but as of now, the public is not being served in accordance with its perceptions of what a modern, well-run system should be.

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Exhibit 1

Infrastructure Planning Disaster
The Washington Metro

This vignette brings together almost all the pathologies of public planning for the public benefit. The D.C. Metro, as the Pruitt Igoe of mass transit, illustrates many of the problems of doing well even what we know how to do.

The D.C. Metro is visually attractive, gets you where you are going, and is reasonably clean. After that, there is not much good that one can say.

1. The D.C. metropolitan area is undergoing rapid growth, yet Metro is designed as a single track 100-mile long system. The design precludes the system's expansion to dual tracks for express trains without taking 100% penalty in new construction.
2. The stations are designed not for people. They are too dimly lit for reading. Early in the morning, you find people stretched out like beads on a string, each one standing under a torch lamp to get a little bit of light on their morning paper.
3. The system is designed so that the lighting cannot be easily increased. In the middle of the energy crisis, they could not figure out while building the system how to remove the light-wasting opaque housings around the lights.
4. The stations are designed to have no shops and no kiosks. Yet we have known for 20 years, from the work of Oscar Newman, that public space crowded with people is safe. The designers threw away solid information that offered a solution to a security fear and an aesthetics problem (litter and vermin).
5. The fare system is asymmetrical - you pay more to go in one direction than the other, if you use a bus connection. The designer could not figure out a single fare scheme for a multi-mode ride.
6. Snow stops the system, although when weather is bad, more, not fewer, people want public transportation.
7. The connection to the airport is simply a public outrage. You get off Metro, an eighth of a mile from the terminal - it is in sight but out of reach. With 20 pounds of luggage in each hand, you now have a choice: either you wait 15 minutes for the jitney or scurry on foot to a heart attack. Now, why did that happen? One official's story is that one system changed its plan without telling the other. Another version is that one-third of the revenue for the airport comes from the parking fees.
8. The Metro stations were designed so that NASA could use them as wind tunnels.

9. The physical and aesthetic design of Metro stations is utterly homogeneous. You cannot tell where you are by looking at the station. No sense of the nation's capital is reflected in its design - a monolithic, curved concrete waffle.
10. Metro was designed in a way that precludes the opportunity to learn in the course of its own construction to do a better job.
11. The cars are designed by aerospace engineers who have never ridden on mass transit - the vehicles have curved walls. If you are standing by the door, every time the car lurches forward, you are slammed against it. The ceilings at each end of the cars are depressed. About one male in 500 runs the risk of a neck compression on standing up after taking a seat at either end of the car.
12. The maps in the cars are nearly useless - ironic in tourist city.
13. The bars for standing passengers to hold onto are so high that anyone under 6 feet must hold the bar with a stiff arm. This assures that when you most need support, when the car lurches forward, you either let go and fall, or wrench a joint. Recently, the bars were lowered, so that anyone over six feet four inches risks a head injury anywhere in the car. As an occupational hazard it would be an outrage; as public transportation it is supposed to be good design.
14. The upholstery? Incredibly, the seats have upholstered square corners---to stand 500,000 abrasions.
15. The floor tile is slick when wet.
16. The escalators succumb to the weather. They are half outdoors.
17. The carpets are uncleanable. In wet weather, the smell of mold from the damp carpets can be overwhelming.
18. The station platforms are designed below the capacity of the trains, with little room for expansion. There are no stairways as alternatives to the escalators.

Source: Coates, J.F. & J. Jarratt. "The Potential Benefits from Science Engineering for the American Infrastructure," for the National Council on Public Works Improvement, July 1986.

POLITICAL AND FINANCIAL CHALLENGES OF INFRASTRUCTURE RENEWAL

The Honourable James Bradley
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Toronto, Ontario

ABSTRACT

The deterioration of Canada's infrastructure is a rather insidious phenomenon. Because sewer pipes and watermains are out of sight and therefore not part of the public's conscious awareness, their need for rehabilitation will not become an issue of concern until the opening of a faucet no longer delivers clean, safe water. But it should never reach such a crisis; for, to rehabilitate the urban infrastructure now is financially more justifiable than its reconstruction later - more justifiable from the point of view of both the legacy we leave to future generations and the conduct of good business. The rehabilitation of Canada's urban infrastructure, however, will incur costs that can only be responsibly managed through the cooperation of all levels of government.

RÉSUMÉ

La détérioration des infrastructures urbaines du Canada se fait de façon insidieuse. Comme le public ne voit pas les canalisations d'égouts et le réseau d'aqueduc, il ne prend pas vraiment conscience de leur existence, ni de la nécessité de les réparer, aussi longtemps que son robinet lui apporte de l'eau propre et potable. Cependant, on ne devrait jamais en arriver à ce point, parce qu'il est plus facile de justifier les frais nécessaires pour réparer les infrastructures aujourd'hui que ce ne le sera pour les reconstruire plus tart - c'est plus facile du point de vue du patrimoine des générations à venir, ainsi qu'au plan de la gestion des affaires - . La réparation des infrastructures urbaines du Canada suppose toutefois des frais qui ne peuvent être assumés de façon responsable qu'avec le concours de tous les orders de gouvernement.

Each summer, beaches are closing across Ontario as a result of water contamination from sewage and storm run-off. Our drinking water supplies are taken from the same waters into which we discharge our wastes. New industrial chemical wastes entering our sewers requirethat we upgrade our abatement systems. And our infrastructure is growing older, requiring substantial upgrading, if we are even to keep pace with our current pollution control.

The Province of Ontario can and wants to do something. However, the federal government, after helping out for so many years, has curtailed funding for infrastructure renewal.

In Ontario, we are confronted with an aging and decaying sewer and water system, a system that represents an investment of about $30 billion. We must spend money to prevent future crisis situations. We must spend money now to save money in the future. We must spend money to protect the health and safety of our citizens. We must spend money to maintain our status as a good place in which to invest and build.

Allowing these facilities to deteriorate further could cause damage to the environment and risks to the health of Ontario's population. Watermains will suffer from calcium build-up and crack, leaving the people they serve at risk from contaminated water. Groundwater will become contaminated by leaks from sewage systems, and sewage treatment facilities will be overloaded by the inflow problems associated with old, outmoded combined sewer systems.

The Federation of Canadian Municipalities said that we must spend $14 billion on infrastructure over the next 5 years simply to protect the investment we have already made.

We are already beginning to see the warning signals in some municipal systems. There are broken mains. There are infiltration problems. In many cases, we have not yet even done the assessments that will tell us just how much trouble we are facing.

In Ontario, we have started the process of determining just how much work there is to be done. My ministry is spending millions of dollars to help municipalities plan rehabilitation programs for water and sewer work, and to identify local pollution problems from surface run-off and from municipal and industrial discharges. The municipalities are meeting us half-way, dollar for dollar, to begin this work.

Measured against the needs that exist, both for studies and for actual rehabilitation work, we are not spending much. At this stage, there is, truthfully, not much more we can do.

The problem also has an international dimension. We are bound by treaty obligations with the United States to maintain the water quality of the Great Lakes and other waterways. The accelerating decay of our capacity to treat sewage may affect our meeting those obligations.

All three levels of government must participate in sharing the costs of this rehabilitation. The financial burden of the work, even now when it is still relatively cheap, that needs to be undertaken simply cannot be borne by municipal governments alone. It is also beyond the scope of provincial governments acting in concert with their towns and cities.

The task that lies ahead requires the active co-operation of all three levels of government. It also requires foresight, imagination, and courage.

The problem of infrastructure renewal, by its very nature, is not one which can justify war-time levels of spending. The nature of the problem we face is that it is not the kind of thing that arouses great excitement or urgency.

There is no single, looming threat. There is no atmosphere of urgency. The situation has not yet prompted politicians to mount a decisive and bold attack. But that is what it requires.

This is not a plant closing or a flood of cheap foreign imports that threaten our livelihoods and our communities. Yet it will cost us jobs and investment in the future. Of that I am certain. I will return to this in a few minutes.

It is not an immediate crisis such as an oil spill or chemical accident, although it will ultimately be as damaging to the natural environment and the quality of human life.

The accelerating breakdown of municipal sewers and water pipes is not visibly depriving people of natural beauty in the form of vanishing wildlife and dying trees, although that will be the inevitable impact of a crumbling infrastructure.

Infrastructure renewal is important and necessary, but unfortunately, it is just the kind of investment that is postponed in favor of more immediately-perceived needs. No one denies the need for it, but no one has done anything about it. Until now. The political effort must begin now.

Public works are taken for granted, in large part. The status quo is comfortable. A generation has grown up with public services that are essentially invisible. When we flip a switch, the lights go on. When we open the faucets, clean, fresh water comes out. People have unconsciously placed a lot of faith in our electric, water, sewer and road systems. Members of the public believe they have a right to services that run smoothly, cheaply and uninterruptedly, year after year.

Money spent on building original municipal services is money well spent. Such projects make it possible to create communities with opportunities for employment and recreation, and high standards of health and safety. Money spent on renewing municipal services is money well spent. The lifetime of water distribution systems, sewers, and roads can be extended far into the future with responsible and timely maintenance and repair.

But money spent on totally replacing failed and useless municipal services is in large part money wasted. In effect, by postponing tough decisions now, we are wasting money that is not ours. We are not merely frittering away a valuable inheritance through neglect, we will be placing an unnecessary burden on those who follow us.

Money spent on infrastructure projects is money that for the most part stays in Canada, in the form of wages and in the form of Canadian materials and equipment.

Money spent on municipal infrastructure projects brings with it a high multiplier effect. Increased economic activity and higher levels of employment return a high percentage of that money to all levels of government in the form of direct and indirect taxes. The quality of life is ensured and improved, not just for individual citizens but for business enterprises of every kind.

Some jurisdictions in this country are already suffering loss of business due to deteriorating services. But the converse can also be true. When business leaders see governments making responsible, long-term investments in their own communities, they are much more willing to do the same.

Corporations look at many factors in their location decisions. They want long-term health and quality of life for their employees. They think about protecting and enhancing the value of the land they lease or purchase. And they look for the highest possible standard of transportation, sewer, and water services possible, consistent with their own objectives.

Spending money to support the built-environment of our towns and cities now will most certainly stimulate investment, create employment, and result in a higher level of economic activity to the benefit of everyone. Expenditures now, large as they are expected to be, create jobs in the present and in the future.

If we leave the towns and cities of Canada in a deficit position in the future, it will be a clear sign of failure of will and imagination. Every period of time brings its own challenges and its own sacrifices. This one is ours.

Ontario has taken the first few steps in determining the real extent of the job that lies ahead. That job, the renewal of our infrastructure, can only be achieved through co-operation. The federal government must join with the provinces and municipalities of this country in this undertaking, and it must do so with haste. Historically, the federal and municipal governments have been our partners in this work. In practical terms, we look to the federal government as the only institution with the resources to make these projects happen.

The position of my ministry and my government is clear. I believe that from coast to coast, provincial governments have taken clear positions as well. This work must be done.

We must make a beginning soon. Every day of delay drives the costs higher and narrows our range of action.

Canada and all its regions want to enjoy the benefits of an industrialized society, without sacrificing the quality of the environment, or human life and health.

We want to maintain our natural environment, and at the same time increase our international competitiveness.

We must make the responsible and courageous decisions now, before it's too late. In both a literal and figurative sense, the foundations of our country are at stake.

FEDERAL, PROVINCIAL AND MUNICIPAL CO-OPERATION: PAST, PRESENT, AND FUTURE

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ABSTRACT

Historically, all three levels of government - municipal, provincial and federal - have been involved in financing urban infrastructure. The first part of this paper describes their respective roles, including federal and provincial conditional grants, and the property taxes, user charges and debt-financing arrangements of local governments. It also looks at past funding levels and shows the dramatic decline in the involvement of the provincial and especially the federal governments.

The second part of the paper uses economic analysis to determine the appropriate level and type of involvement for each level of government. Based on economic principles, the paper provides some guidelines for the future funding of urban infrastructure.

RÉSUMÉ

Jusqu'ici, les trois ordres de gouvernement - municipal, provincial et fédéral - ont participé au financement de l'infrastructure urbaine. Dans la première partie de leur exposé, les auteurs décrivent le rôle de chacun et font mention des subventions fédérales et provinciales conditionnelles, ainsi que des taxes foncières, des frais d'utilisation et des arrangements de financement de la dette des administrations locales. Ils examinent également les niveaux de financement assurés dans le passé et font ressortir la diminution notable de la participation des gouvernements fédéral et provinciaux, plus particulièrement celle du gouvernement fédéral.

Dans la seconde partie, ils se servent d'une analyse économique pour déterminer le degré et le genre appropriés de participation de chaque ordre de gouvernement. Invoquant divers principes économiques, ils établissent certaines lignes directrices pour le financement des infrastructures urbaines dans l'avenir.

INTRODUCTION

The major role of local government is to provide goods and services to its residents. The federal and provincial governments are responsible for stabilization policy (ensuring an adequate level of economic growth, stable prices and low unemployment), and for redistribution through tax and transfer policies. Local governments are too small to be successful in tackling either of these two functions. However, they are well suited for the provision of goods and services such as education, parks, recreation, roads, water, sewage, and other so-called "local" services. In fact, local governments are the most appropriate of all three levels of government for providing these services, because they are most responsive to local needs and demands (for example, Tiebout, 1956).

To finance these local services, municipal governments rely largely on property taxes and provincial grants, with each of these revenue sources accounting for between 40 and 50% of total revenues depending on the municipality. The remaining 10% or so of local revenues are derived from user charges such as water fees, parking violations, and other fees. Debt-financing is used, to some extent, to finance capital expenditures and some limited federal funding has been used for providing new infrastructures.

Reliance on the property tax decreased somewhat in the 1970s but has been on the increase since the beginning of the 1980s owing to a reduction in provincial grants to municipalities. The use of debt-financing has also been on the decline because of high interest rates in the early 1980s which made this source of financing very expensive.

The consequence of the decline in provincial grants (and federal grants) and the decreased use of debt-financing for urban infrastructure has been a rapid deterioration in the capital facilities and a lack of strategy to deal with it. The deterioration in urban infrastructure in Canada has been well documented, for example, by FCM in its 1985 study.

The major responsibility for municipal infrastructure (roads, bridges, sidewalks, sewers and water distribution, and sewage and water treatment) rests with local governments. The primary responsibility for funding these services also rests with local governments. However, there may also be a role for other levels of government in the financing of urban infrastructure.

The purpose of this paper is to describe and evaluate the role of all three levels of government in the financing of urban infrastructure.

RATIONALES FOR FEDERAL AND PROVINCIAL ASSISTANCE

Although infrastructure is best provided by local governments, and thus the primary responsibility for its funding should be taken by local governments. Economic analysis provides three rationales for federal and provincial government assistance. Each of these is discussed in turn.

Spillovers

Perhaps the strongest justification for federal and provincial government involvement in the funding of urban infrastructure is provided by the spillover (or externality) argument. The benefits (or the costs) of many of the services of urban infrastructure are not necessarily confined to the local muncipality that provides them. For example, municipalities situated on Lake Ontario, or on the St. Lawrence River, which do not treat their wastes properly will affect residents of other municipalities situated along the same body of water. Without adequate sewage treatment, it will be difficult to control disease, improve sanitation, and so forth.

Another example of a spillover might be a road that goes through one municipality but is used by residents of other municipalities as well. The benefits go beyond the jurisdiction in which the service is provided.

A problem arises because there is no incentive for any one municipality to take account of the benefits of sewage treatment, or roads, or whatever service on the residents of other municipalities in its decision on how much of that service to provide. Each municipality decides on how much to provide to its residents who are paying for the service. It does not want to charge its residents for services enjoyed by others outside the jurisdiction.

Where the benefits of infrastructure construction or maintenance go beyond municipal boundaries, some incentive is required to encourage the municipality to provide the appropriate level of service from the perspective of all who will benefit from it. One way to do this is to transfer funds to that municipality. Where the spillover benefits extend to the region, a transfer from the regional government is appropriate. Where the benefits are provincial in scope, a provincial transfer is appropriate; and where the benefits are national in scope, a federal government transfer is appropriate.

To encourage spending where there are spillovers, the type of grant required is a conditional, matching transfer. It would be conditional on being spent on the service exhibiting the spillover, and it would be matching whereby the donor government would pay a percentage of the expenditures on the service reflecting the magnitude of the spillover. Thus, if it is anticipated that 25% of the expenditures spillover to residents outside the jurisdiction, then the provincial (or federal) government would fund 25% of the expenditures.

In theory, a conditional, matching transfer which internalizes the spillover would solve the problem. In reality, however, it is difficult to determine the appropriate matching rate. How much of the benefits of a highway constructed in one municipality spill over to residents of other municipalites? How much will disease be reduced for residents of neighbouring municipalites if one municipality cleans up its waste adequately? These are tough questions to answer because spillovers are difficult to measure. At the very least, it needs to be determined how broad are the spillovers - regional, provincial, or national - to know which level (or levels) of government should provide the transfers to municipalities.

Fiscal Equity

A second economic rationale for funding of urban infrastructure by senior levels of government is fiscal equity. The equity objective is to allow municipalities to provide at least some minimum national standard of service without having to levy unduly high tax rates.

There are three reasons why this may not be possible to do in the absence of intergovernmental transfers. First, tax bases differ across municipalities so that a low tax base jurisdiction will have to levy a higher tax rate than a high tax base jurisdiction to make the same level of expenditure. Second, costs may differ. It is much more expensive to build a two-lane highway through the Rocky Mountains than across the Prairies, for example. Third, needs may differ: the needs of larger cities may differ from the needs of smaller cities; the needs of older cities may differ from the needs of newer cities and so forth.

To ensure minimum national standards, conditional lump sum transfers are required from the federal government. If provincial standards exceed those of the federal government, then conditional lump sum transfers should also be provided by the provinces.

In addition, to conditional lump sum transfers, the senior levels of government could assist with the debt finance of municipalities for urban infrastructure. They could borrow on behalf of muncipalities, provide loan guarantees or lend to them directly at lower interest rates and, in essence, provide a form of conditional grant.

The National Character of Urban Infrastructure

One rationale for federal funding of urban infrastructure that is very popular in the literature suggests that infrastructure is the "underlying framework" or the "backbone" of urban Canada and basic to the national economy. The Association of Municipalities of Ontario (AMO) states it this way:

> The health and welfare of our citizens and of the national economy requires well-functioning infrastructure. It has often been said that the whole is no greater than the sum of its parts. Therefore, the vitality of Canada and the strength of the Canadian economy depend to a large extent on the soundness of municipal infrastructure (AMO, 1985).

In other words, if we do not provide roads to get the workers to the factories, then our economy will not be productive.

This rationale for federal involvement, although not incorrect, is probably the weakest of the three. This argument could be used for most of the services provided by government, such as health care, education, social services, and others. Should the federal government fund all of these services?

Summary

The strongest case for federal and provincial assistance for the provision of urban infrastructure derives from the spillover argument. Where the benefits of infrastructure (or the costs) are felt beyond the jurisdiction in which the service is provided, another level of government can improve the allocation of resources by transferring conditional, matching funds to the municipality.

Transfers can also be justified on the grounds that they ensure that minimum standards of service are provided wherever one lives in the country. To a lesser extent, grants can be justified on the basis that there is a national character to urban infrastructure.

There is one caveat, however. There are also costs to muncipalities of having substantial federal and provincial government funding of infrastructure in terms of the potential loss of local autonomy. The types of services to be provided and how they are to be provided are decisions appropriate for local governments. With intergovernmental funding usually come strings that result in some of these decisions being made by the donor governments. As will be noted below, federal funding in the past favoured new facilities rather than the repair and maintenance of existing facilties. This is the kind of decision -- construction versus maintenance -- that is probably best made at the local level.

Trends in Federal, Provincial and Municipal Funding

Each level of government is responsible for some aspect of urban infrastructure. Some public works are advantageous to the whole country, or to two or more provinces, and are, therefore, financed by the federal government. These include airports, harbour facilities or the Trans-Canada Highway. Similarly, there are facilities that are a provincial responsibility, for example provincial highways, and there are a broad range of municipally provided services which require local infrastructure expenditures. Included in the municipal infrastructure are roads, bridges, sewer and water facilities, and distribution systems.

The services mentioned above are all considered to be "physical overhead capital" or infrastructure, which serves primarily an economic function, as opposed to "social overhead capital", which relates to infrastructure that provides a social or redistributive function. Examples of this type of infrastructure include educational facilities, social housing, as well as hospitals and health facilities. This paper focusses on the trends in financing of physical overhead capital since this has been the focus of the major studies such as that of the Federation of Canadian Municipalities (FCM, 1985). This focus is taken since it is this infrastructure which is the primary responsibility of local government; while many of the social facilities, although located in urban areas, are the responsibility of provincial governments.

Prior to examining the recent history of infrastructure financing at the three levels of government, two points should be made. First, in examining funds that are available for infrastructure renewal, it is necessary to consider all funds that are made available for the infrastructure: new, renewal and maintenance. This is necessary due to the substitution which might be made between expenditures for new infrastructure related to growth and those for the replacement or maintenance of existing facilities. Second, it must be recognized that the country's public finance system could be viewed as a downward cascading system with respect to intergovern-mental transfers. The federal government gives grants to the provinces, and to a lesser extent, to local governments, while the provinces also give grants to local governments. This suggests that a reduction in overall expenditures for infrastructure expenditures by a senior government may impinge upon the funds available to local governments. Due to this potential top-down influence, the financing trends of the federal government will be examined first, followed by provincial and local governments.

Federal Trends

The objective of federal assistance to local governments for infrastructure has not always been primarily for the provision of infrastructure. Rather, in the early years, the objective was to alleviate unemployment. Where the objective of the funding has been related to the quality of infrastructure, the focus has been on the provision of new facilities rather than the maintenance or replacement of existing facilities.

The earliest federal assistance was provided from 1938 to 1940 under the aegis of the Municipal Improvements Assistance Act. This program provided loans for water and sewage improvement projects. A primary objective of this program was to provide jobs and therefore reduce unemployment. This approach of "make work" legislation or increasing employment through capital works was continued with the enactment of the Municipal Development and Loan Act. During the period from 1963 to 1966, this program provided assistance for sewage and transportation systems.

Within the context of economic objectives, the Department of Regional Economic Expansion established the Special Areas Program in 1969. The objective of this program was not solely to provide employment for the specified capital works, but also to attract industry to the areas which were designated to receive the assistance.

It was only in the late 1950s that CMHC began to be considered the federal agency that should become involved in the development and delivery of federal infrastructure assistance programs. Although CMHC's first program, the Sewage Treatment Program, was based on a need to eliminate pollution in groundwater identified in a 1956 survey, it appeared that the legislators passed the funding for the program in response to the brief recession in the late 1950s. Only after the legislation came into effect as an amendment to the National Housing Act, 1953 did the legislators come to the realization that the major objective should not be economic stimulation but pollution control. This realization occurred at a time when the economy began to recover from the recession.

The Sewage Treatment Program was in operation from 1961 to 1974. It basically provided loans some percentage of which were forgivable for the construction of sewage treatment and collection systems. During the life of this program, $979 million was provided in loans, and $131 million in grants which were the forgivable components of the loans. (See Table I)

The second program administered by CMHC was basically an extension of the Sewage Treatment Program. This assistance known as the Municipal Infrastructure Program was in existence from 1975 to 1978. Under this program, both the range of grants and the types of projects made eligible were increased. In addition to the previous objective of pollution abatement, a second objective of encouraging land management in undeveloped areas was included. The intent of this second objective was to provide assistance for infrastructure for new development areas rather than redevelopment of infill areas. During this program's existence, over $1 billion of assistance was provided in loans and an estimated $395 million in grants.

A program initiated in 1973 which was targeted exclusively for existing built-up areas of municipalities was the Neighbourhood Improvement Program (NIP). This program was intended to provide funding on a cost-sharing basis for improvements to the public infrastructure in selected low-income residential areas. In addition to sewer and water distribution systems being eligible expenditures under this program, parks and recreatonal facilities were also eligible. The cost sharing was on a 50/25/25 federal, provincial, local basis.

The final federal program was the Community Services Contribution Program (CSCP), which was in existence from 1979 to 1980. This program was enacted under the 1979 National Housing Act and effectively replaced the Municipal Infrastructure Program as well as the Neighbourhood Improvement Program. Although the objectives of this program remained the same as those of the Municipal Infrastructure Program, both the range of services for which funding was made available and the method of delivery were changed. Under this program, funds could be used for other community services as specified in the federal-provincial operating agreements. This allowed for funding related to social and recreational facilities in addition to the sewer and water projects eligible in the earlier program. As with the NIP some funding from this program was used to revitalize existing neighbourhoods. The funding mechanism for this program was in the form of block grants allocated to the provinces based on a population and income formula. During this short-lived program, the federal government provided $221 million in grants.

In summary, the federal infrastructure funding programs have gone through three phases. Initially their objective was economic in nature, i.e., for either employment or economic development. The second phase, in which the programs were administered by CMHC, had the primary objective of providing adequate quality services for new developments. During this phase, 1960-1980, there was an upward trend in the funds made available until the final two years, when the Community Services Contribution Program was instituted. The final phase, which we have been experiencing since 1980, is the virtual nonexistence of any federal infrastructure programs for local government.

TABLE I

SUMMARY OF CMHC MUNICIPAL INFRASTRUCTURE ASSISTANCE 1961 TO 1980 (1)

Program	No. of loans/grants	Loans ($000,000)	Grants(2) ($000,000)
Sewage Treatment Program (1961-74)	2,896	$979	$131
Municipal Infrastructure Program (1975-78)	1,618	$1,025	$395(2)
Community Services Contribution Program (1979-80)	1,613	---	$221
Total	6,127	$2,004	$747

(1) Data are in unadjusted dollars, i.e. not adjusted for inflation. They include some municipal estimates for projects not finalized.

(2) This includes loan forgiveness, high cost grants (1975-79 only), and grants to non-NHA financed projects (1975-78 only).

SOURCE: Paul Bircham and Wayne Bond, "The Impacts on Land Use of CMHC Infrastructure Assistance, 1961 to 1980", Lands Directorate Environment Canada, Working Paper No. 32, March, 1984.

The funding that was made available through these programs was primarily intended and used for the construction of new facilities except for the NIP funding and some funds during the short period of the CSCP. The nature of the funding in all programs regardless of whether it was in the form of loans or grants was conditional upon the type project for which it was to be used, and was matched with provincial and/or local government dollars.

Provincial Trends

It must be noted that the ability of provincial governments to assist in the funding of local infrastructure is in theory quite large. Obviously, local governments receive unconditional grants which may be used for these purposes. However, the allocation of these funds for infrastructure expansion, improvements or maintenance is a local government decision. It might be expected that additional funds might be allocated to these activities if there are substantial increases in unconditional grants, but this has not been the case. Therefore, it is necessary to examine provincial conditional grants to determine whether there have been any significant funding initiatives for infrastructure improvements.

It is somewhat difficult to generalize across provinces since each province has a separate system of grants which it provides to local governments. On average, provincial funding ranges from about 2% of total revenues for water treatment, to approximately 18% for roads and 19% for bridges. Thus, a good example of the nature of provincial funding of infrastructure is provided by a description of provincial grants for road construction and maintenance across Canada.

Generally, provincial governments are responsible for all major highways throughout the provinces, including the components in urban areas. Exceptions to this can be found in Newfoundland, Nova Scotia, and Ontario. In Newfoundland all roads in St John's are a municipal responsibility. The Province does, however, share the capital cost of road projects with municipalities on a 60/40 basis. Nova Scotia contributes a minimum of 50% for constructing, reconstructing or maintaining any street in a city or town that is considered to be a connecting link in a main trunk highway. In Ontario, 50% of the cost of construction and maintenance are contributed to a specific class of local governments, while smaller local government units may obtain up to 100% financing.

A number of provinces not only provide conditional matching grants for construction but also for maintenance. Provinces that provide maintenance funding include Nova Scotia, Quebec, Ontario, Manitoba, and British Columbia. An interesting structure exists in Winnipeg, where the city is responsible for all roads in its arterial street system, but the province provides an annual block grant to assist in the financing of construction and maintenance.

The existence of these grants does not ensure that the funding is adequate to maintain or improve the existing road system. It merely suggests that the mechanism is in place to deliver the funding. An example of lack of funding is Ontario where provincial road subsidy allocations decreased 18.2% from 1975 to 1983 in 1983 dollars (AMO, 1985).

Although not many provincial programs to upgrade infrastructure exist since the cutting of the federal cost-shared programs, one Ontario program, PRIDE (Programs for Renewal, Improvement and Redevelopment), should be mentioned. Under this program $19 million was allocated in grants and loans in 1986. The bulk of the funding, $14.6 million, was to the Ontario Neighbourhood Improvement Program (ONIP), which is essentially the provincial equivalent of the old federal NIP. The remaining $4.4 million was allocated to the Commercial Area Improvement Program (CAIP). This program is intended to upgrade older commercial districts by assisting in the financing of municipal services, parking, and the general streetscape. Although the magnitude of funding may be insufficient to address the infrastructure problem, this program, nevertheless, is a step in the right direction.

Local Government Trends

Local governments tend not to undertake major changes in funding allocations, but rather, they respond to changes in grants from senior levels of government. Local governments tend not to have large increases in their own source of revenues. This section briefly comments on how local governments have responded to reductions in federal-provincial funding and to general economic conditions.

The FCM study demonstrated that municipal public works budgets have been decreasing relative to total municipal budgets. Their survey responses indicate that total public works decreased from about 32% of the total budget to about 27% during the period from 1968 to 1983. Also, the public works capital component decreased from about 16% to about 11% of the total budget during the same period (FCM 1985).

A second impact on municipal expenditures for infrastructure renewal and replacement is a reluctance by local governments to make increased use of debt finance. Recently, there has been a tendency for municipalities to use "pay-as you-go" financing to a greater extent for capital items. This means that capital items are financed out of the current or operating budget and capital expenditures must compete for scarce budget dollars with normal operating expenditures such as education and social services. Many cities in Canada either use "pay-as-you-go" financing or have tight and, in some cases, decreasing limits on total debt finance. Edmonton, for example, has had a "pay-as-you-go" policy since 1978. Other municipalities, such as Halifax and Saint John, have made attempts to reduce their per capita debt by reducing the use of debt-financing. This phenomenon has been in effect since the high interest rates of the early 1980s. This tendency, coupled with absence of federal matching grants and the lack of increases in provincial grants, has resulted in a reduction of the growth of municipal expenditures on infrastructure.

Debt finance is an appropriate way for municipalities to finance urban infrastructure. Economists argue, on benefit grounds, that where the benefits of a facility (for example, a road, school , recreation centre) are enjoyed over an extended period of time, say 25 years, it is appropriate for the costs to be borne over that same time period. In other words, why should taxpayers pay all of the costs of a new facility today when the benefits are to be enjoyed by them and others well into the future? Instead of trying to finance large capital outlays entirely out of today's property taxes, municipalities should borrow the funds and pay them back over the life of the facility. Debt finance can be justified for such projects as the replacement of water and sewage treatment plants, major road reconstruction, major structural repair to bridges, and many other projcts with a long life expectancy and where the benefits fall on future users. This approach provides "inter-generational equity".

As noted earlier, municipalities have been reluctant to borrow in recent years because of high interest rates in the early 1980s. Consequently, there is a role for the province (and perhaps the federal government as well) in helping municipalities borrow funds for capital projects. Provincial governments have greater ability to borrow on capital markets and at lower interest rates than do municipalties. Provinces could, for example, provide guarantees for loan repayment for money borrowed by local governments, or they could borrow money on behalf of the municipalities. Alternatively, provinces could lend the required funds themselves to muncipalities.

A final trend in financing the capital cost of services should be described. Municipalities in a number of provinces have increasingly attempted to shift the financial burden of providing the infrastructure required for new growth onto developers. This has been achieved through the use of subdivision agreements which require the developer to provide all services internal to the subdivision; and the use of development charges, lot levies or impost fees to defray the capital cost of off-site infrastructure. These types of fees or charges are legal, and they are applied in Ontario, Saskatchewan, Alberta, and British Columbia. Not having to finance these facilities can free up some public works funds for infrastructure renewal and maintenance.

The trend to the increasing use of these charges by local governments and its increasing magnitude has been documented in Ontario. Currently, these charges are often in the $4000 to $5000 range per detached dwelling but can go as high as

$7000 (Amborski, 1986). Despite the extensive use of this revenue source, Ontario still has infrastructure deterioration and funding problems.

Summary

This review of the history of infrastructure funding suggests that there has been an overall decrease in funds allocated to infrastructure. At the federal level funding was increasing until 1978, when it began to decline, and then essentially it was terminated in 1980. Provincial funding followed a similar pattern since most of the federal programs required provincial cost sharing. There is also some evidence that unconditional and other infrastructure related grants if not decreasing are not significantly increasing.

This decreased funding has an impact at the local level where the services are provided and, not surprisingly, there has been a relative decrease in municipal public works expenditures. In addition, municipalities have demonstrated an aversion to debt finance. Both of these trends point to a need for concern over the the state of existing infrastructure. However, some jurisdictions have increased the application of user charges to defray the cost of capital facilities for new development. This may have the benefit of freeing up some additional funds for infrastructure maintenance and renewal.

CONCLUSIONS

Primary responsibility for urban infrastructure rests with local government as does the primary responsibility for its funding. However, as this paper has attempted to show, there is a role for federal and provincial governments to provide asssistance to municipalities to construct, maintain and repair infrastructure. First, on the grounds that some types of infrastructure (such as roads and sewage treatment) result in spillovers across jurisdictions, there is a justification for provincial and federal conditional, matching transfers. On the grounds of fiscal equity or the maintenance of minimum national or provincial standards, a rationale has been established for conditional, lump sum transfers and perhaps some form of loan assistance.

The federal government has provided matching transfers and loan assistance in the past but these programs were discontinued in 1980. Provincial governments still provide some matching transfers, especially for roads, and some loan assistance. Municipalities use a combination of these transfers plus property taxes and to a much lesser extent, debt finance. User charges are used by municipalities in some provinces.

In terms of the future, federal and provincial funding for urban infrastructure is not likely to be forthcoming. With changing demographics -- an aging population and more women working -- there will be other pressing demands on senior levels of government. These demands, coupled with continued emphasis on reducing the deficit, make the future prospects for increased funding of urban infrastructure rather gloomy.

Finally, there are some important issues in the area of federal and provincial funding of urban infrastructure that require further research. First, information on provincial funding of urban infrastructure has not been made available on a nation-wide basis. In particular, trends in provincial funding have not been well documented. Second, the impact of federal and provincial funding on municipal spending on infrastructure is unknown. To measure that impact requires a behavioural model of municipal spending on infrastructure to determine what role federal and provincial funding plays. Further research on the impact of various types of federal and provincial funding would provide useful information to policy-makers in the senior levels of government with respect to the appropriate type of assistance they should provide to municipalities.

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DEBT-FINANCING
PAST, PRESENT, AND FUTURE

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ABSTRACT

A variety of techniques is available to municipalities through the Canadian and Euro capital markets to assist in financing needed infrastructure renewal. Among these techniques are:

- major borrowing currencies and instruments on European and Canadian money markets,
- interest rate and currency swaps,
- bank financing through both bought deals and syndicates,
- internal funding, and
- intermunicipal borrowing and pooling.

RÉSUMÉ

Grâce aux marchés canadiens et européens des capitaux, les municipalités ont à leur disposition divers moyens de financer les travaux de renouvellement de l'infrastructure qu'elles doivent exécuter. Les municipalités peuvent choisir, par example,

- principales devises et principaux moyens d'emprunt aux marchés capitaux en Europe au Canada;
- taux d'intérêts et "swaps" de devices;
- financement bancaire par conventions de prise ferme et syndicates financiers;
- financement interne; et
- emprunt et mise en commun des ressources entre municipalités.

INTRODUCTION

The fact that this conference is taking place is in itself a recognition that Canada's towns and cities face a major challenge in rehabilitating deteriorating infrastructure. According to the estimates from the Federation of Canadian Municipalities, this challenge carries with it an estimated price tag of $14 billion. The sheer size of this price tag means that expenditures will have to be staged over a period of time and will probably need to involve a cooperative effort from all three levels of government. The FCM has proposed a 5-year program with the federal, provincial and municipal governments each picking up a third of the cost. Regardless of any additional funding which may be forthcoming from other levels of government, it will be the municipal level that will be most directly involved in the rehabilitation and maintenance of Canada's urban infrastructure. Certainly, those of you at the municipal level are the "front-line troops" when it comes to dealing with residents' complaints relating either to the quality of services or the taxes levied to pay for them.

THE PRUDENT USE OF DEBT-FINANCING

The sheer magnitude of the expenditures indicates that sensible, prudent use of debt-financing will necessarily be part of the answer to the funding problem. One of the major challenges facing the treasurers and financial officers who will be charged with actually raising debt-financing will be to make effective use of some of the innovative financing alternatives which are emerging in the global financial marketplace.

Before we turn to look at specific options, those that are currently available to you and those that may be options in the future, let us stop for a moment to catalogue some of the other sources of funds that may be available.

Inter-governmental transfer payments will form part of the funding. Realistically, however, the federal and provincial governments are trying hard to reduce their own deficits and their ability to take on more commitments is limited.

In recent years, we have seen increased emphasis on a "pay-as-you-go" philosophy in Ontario municipalities. Metropolitan Toronto, for example, has a policy of financing 50% of net capital requirements from current revenues with any excess or deficiency being transferred to or from a capital financing stabilization reserve. This policy has been the most important contributing factor in the continuing decline of Metro Toronto's long-term debt and debt service costs. As a resident of Etobicoke, one of the cities that is encompassed within the municipality of Metropolitan Toronto, I can personally appreciate the merits of this policy. However, "pay-as-you-go" has limitations. If, for example, Etobicoke were to undertake its own 5-year infrastructure renewal program and decide to finance it entirely out of current tax revenues, I shudder to even think what my property taxes might be. Realistically, a municipality's actual ability to fund infrastructure renewal through tax increases is limited - you are all familiar with the taxpayer revolt that led to Proposition 13 in California. Therefore, while "pay-as-you-go" is obviously going to play a part in meeting funding needs, it is not the whole answer.

User charges maybe part of the answer. User fees might provide not only additional revenues, but also serve as a strong incentive to encourage conservation and efficient use of facilities. Counter-arguments can be made, however, that user charges constitute a regressive form of taxation, falling most heavily on those segments of society least able to afford them.

When all the various sources of funds have been catalogued, and their potential evaluated, we come back to where we started. Infrastructure renewal is going to have to be financed in part by debt.

There sometimes seems to be a perception on the part of the public that debt incurred by the public sector is somehow inherently wrong. Actually debt is really just a business tool. Properly used, raising money by borrowing is sound business practice. The tool of debt-financing allows you to recover the costs of facilities from your customers over the life of the facility. It would be unfair and unacceptable to current customers to include in their taxes the full cost of services and facilities that will be used over many years and which will benefit future users.

GLOBAL FINANCIAL MARKETS

The world's capital markets are experiencing a revolution. The world-wide process of deregulation, combined with the development of powerful new financing techniques and communication improvements have brought capital markets around the world much closer together. Let us review the changes that have taken place and what they mean regarding the present and future financing options available.

Deregulation

Until 1981, banks in the United States were regulated by law (Regulation Q) as to the maximum interest they could pay on deposits. High rates of inflation and interest in the 1970s made savers much more sensitive to the rates of interest they received on their accounts and many fled the banking system to take advantage of higher returns available in money market funds. The regulators in the United States eventually recognized the realities of the market place and abolished Regulation Q to let banks compete on equal terms. This process of deregulation continued and accelerated and is still going on. The United Kingdom ushered in the "big bang" last fall. Japan is deregulating rates. Canada is wrestling with financial industry restructuring, and Bay Street, too, is preparing its own version of the "big bang."

Disintermediation

Traditionally, banks have played the role of financial intermediary: pooling funds from depositers and on-lending them. Disintermediation is the process whereby banks are cut out of this process. Borrowers now raise money directly from investors without going through the banks. Two aspects of deregulation have contributed to this process. Deregulation has pushed up the cost of bank deposits (and loans) and therefore given borrowers a strong incentive to seek lower cost means of financing. Secondly, deregulation has also allowed other financial institutions to do things which were once the exclusive preserve of commercial banks.

Securitization

As companies rely less on traditional loans and more on security-type products, such as commercial paper and junk bonds, business has shifted away from commercial banks to investment banks. Commercial banks have responded; and today, many of the so-called "lending products" available from commercial banks are virtually indistinguishable from securities.

Innovation

The advent of new borrowing instruments, spurred on in part by deregulation and in part by new technology, has brought international and domestic capital markets closer together. A bond issuer can switch between domestic and foreign markets, depending on where the best deal is. Probably the single most important innovation has been the development of swaps, interest rate swaps and currency swaps. Swaps, in theory, allow any borrower and any investor access to any capital market in the world. It has been said that the swap throws all interest-bearing instruments everywhere in the world into one big melting pot.

These basic forces of deregulation and innovation, along with the advent of on-line databases, international communication systems, and sophisticated analytical tools, have fundamentally changed the financial markets which a borrower can tap. The cheapest source of funds at any given time may be in a market not previously accessed.

THE EUROMARKET

The term "Euro-dollar" was originally used to describe U.S. dollars which were deposited with banks in Europe. The markets were developed in Europe in the 1960s and have grown to the extent that today funds are raised for corporate entities, sovereign entities, and municipalities the world over in virtually any amount; in some cases as much as $4 billion at one time. The Euromarkets today include many different currencies: U.S. dollars, Yen, Sterling, Deutschmarks, and Canadian dollars, and the market is no longer confined to Europe.

As an indication of the size of the market, in 1985, the equivalent of U.S. $135 billion was raised in the Euromarket. In the first 8 months of 1986, over $120 billion in debt issues were completed. In short, the Euromarket has shown it has size and durability. At the same time it has an ability, unparalleled in any domestic market, to retain the flexibility to adapt to changed conditions and innovative products.

The Canadian dollar sector of the Euromarket got its start in 1975 as a result of changes in withholding tax legislation in Canada, and had grown to become a $4 billion (Canadian) market by 1986. The interest shown in Canadian dollar bonds on the part of European investors has varied to some extent over the years with the relative strength of our dollar against that of the United States. Recently, both currencies have performed strongly relative to European currencies, and international investors have been happy to invest in Canadian dollar bonds because the interest rate differentials between Canada and the United States have historically been at high levels.

As the market has grown, the average size of new debt issues has increased. In 1975, issues were sometimes as small as $10 million and never greater than $35 million. Today the market can easily accommodate issues of well over $100 million and the average size is probably in the area of $75 million. The Euro-Canadian market has reached a stage where it is relatively mature and has the confidence of issuers, banks and, most important investors. Certainly, it represents a source of funds which can be tapped to assist in financing infrastructure renewal.

PRACTICES FOLLOWED BY SOME CANADIAN MUNICIPALITIES

Now to turn for a moment to the practices Canadian municipalities have been following. I am most familiar with the Ontario situation and I would like to talk briefly about what our municipalities can and cannot do under the provisions of the Ontario Municipal Act. Although legislation in other provinces is essentially similar, some points may not be entirely applicable to other jurisdictions.

The Ontario Municipal Act seems a fairly restrictive piece of legislation when it comes to long-term financing alternatives. It is a piece of legislation that was drafted at a time when municipalities were relatively unsophisticated about financing, a piece of legislation designed to keep things under control and ensure municipalities did not get themselves into financial difficulty.

Under the Ontario Municipal Act, capital expenditures which require long-term financing (long-term being defined basically as beyond the term of council) first have to be approved by the Ontario Municipal Board. From a lender's or investor's point of view, it is good to know that the debt service requirements associated with a new issue have been reviewed and approved.

When it comes to actually issuing debt, however, the Act talks only in terms of debentures carrying a fixed rate of interest. Certainly, fixed-rate financing has its merits. It is the most conservative way of ensuring that the local taxpayer is not exposed to the risk of interest rates. It is the most conservative way, in fact, in today's financial marketplace, it is too conservative. It may have been appropriate at one time to keep unsophisticated municipal treasurers out of trouble. However, the financial professionals running large municipalities today hardly need to be restricted and controlled to this extent. Today's chief financial officer in a large municipality is a professional, the equal of a sophisticated corporate treasurer.

I am not saying that Canadian municipalities have not gone to the international capital markets: they have. A number of Ontario municipalities tapped the U.S. market in the 1970s. That was when the Canadian dollar was worth $1.05 in U.S. currency. The municipality would now have to buy U.S. dollars to repay it, with Canadian dollars worth about 75 cents U.S. each. Some borrowers experienced significant foreign exchange losses as a result of borrowing in foreign currencies. Keep this experience in mind when we talk about swaps and the ability to eliminate foreign exchange exposure.

Canadian municipalities have also been tapping the Euro-Canadian bond market. No foreign exchange exposure is assumed because Canadian dollars are borrowed. The first Canadian municipal borrower to test the Euro-Canadian market was the Municipal Finance Authority of British Columbia, which arranged a $25 million issue in 1975. Since then many others have followed suit and Canadian municipalities have now issued more debt in the Euromarket than any other nationality or municipality. Since 1980, about 75% of Euro-issues by Canadian municipalities have been negotiated by municipalities in Quebec. In total, municipal issues account for roughly 8% of all issues by Canadian borrowers.

What is required to go to Europe? First, the size of the financing has to be relatively large. It is now estimated that $30 million is the smallest amount that makes sense economically and from the point of view of selling the bonds. Second, European investors are less familiar with Canadian cities and therefore will rely on credit ratings.

PRESENT AND FUTURE OPTIONS

In presenting a few more details about present and future options, I will be focussing on what they can do for you, not on how they work in technical detail.

The Euro-Canadian Bond Market

At times this market may provide cost savings and an extra source of funds when the depth of the domestic Canadian market is not sufficient to accommodate municipal needs -- two good reasons why Canadian municipalities are already using it. For a borrower who is considering a Euro-issue for the first time, the services of a lead manager who is familiar with the market should be sought to assist in arranging the issue. If I may be permitted a brief commercial, I might note that Orion Royal Bank, our London-based merchant banking arm, has managed a greater volume of issues for Canadian municipalities in Europe than any other investment house.

Swaps

Whether swaps are a present or future option depends on how you use them and the legislation under which you operate. Swaps have developed within the past few years into a multi-billion dollar market today. In fact, it is estimated that 70% of the Euromarket is now swap-driven. Let us start with some definitions for two basic types of swaps: cross-currency swaps and interest rate swaps.

Types of Swaps. The currency swap was the forerunner of the interest rate swap. Principal and interest obligations in one currency are swapped for principal and interest in a second. The swap eliminates exchange risk for both principal and interest, thereby locking in the cost of funds regardless of future currency fluctuations. Is a currency swap an option for an Ontario municipality? It should be. Remember those U.S. dollar bond issues in the early 1970s? With the swap market available today, those issues might be swapped into Canadidn dollars. Would this add to the cost? Not necessarily because this depends on the relative values of the Canadian and U.S. dollars. But keep in mind that some of that foreign low-interest rate debt is turning out to be more expensive than expected when the foreign exchange losses are taken into account.

From swapping currencies, it was conceptually a logical step to swap one type of funds for a second type of funds within the same currency. The Interest Rate Swap enables one party, for example, to issue floating-rate debt and exchange it for another party's fixed-rate debt. Although the first swaps were arranged between two counter-parties who had offsetting needs (and a relative advantage in issuing either fixed or floating rate debt) the market has grown to the point where swaps are traded by the banks on a "book basis". In the same way a client can buy or sell foreign currencies on a forward basis through a bank, he can now arrange a swap and the bank balances off its own swap book on an aggregate basis.

Can an Ontario municipality use an interest rate swap to do long-term fixed-rate financing? That's a matter of interpretation. In theory, yes. The municipality could issue floating-rate debt, such as bankers acceptances (B/A), and enter into a swap to end up with a fixed cost of funds. The Province of Ontario has ruled that B/A's are not an eligible form of borrowing for Ontario municipalities, but that's another story. In practice (and based on discussion with our clients) the first step of issuing floating debt would technically contravene the Ontario Municipal Act which calls for long-term debt to be at fixed rates. You see the problem. With a swap, the actual debt is floating. The swap is a separate contract which is used to achieve a fixed cost when everything is taken into account. Should municipalities be able to use swaps? Absolutely!

Swaps as Debt Management. Debt management once consisted of arranging a debt issue. When the funds were received, all that was left was to send out the principal and interest cheques on the due dates. This is not the way our corporate clients are managing debt today. Swaps have given the corporate treasurer a tool he can use to manage short- and medium-term debt actively. They will swap from floating to fixed and back again if the market, or their view of it, changes. This involves some risks. If they guess wrong, they may wind up back where they started, or worse after paying the bank's fees. Some corporate treasurers would argue equally strongly, however, that to allow long-term debt to simply run to maturity is also a form of speculation. They would say that treasurers cannot afford not to manage their debt. You cannot just leave your debenture debt and forget about it. You must take your chances and anticipate rate movements and take positions.

Can municipalities use swaps in this way to manage long-term debt? Not in Ontario. Should they be able to? Yes, I think so. Remember, not managing entails some costs too (but, I must admit that "not managing" is politically a lot safer).

The cross-currency interest rate swap puts together exchanges of both currencies and interest rate swaps. The borrower swaps a floating-rate U.S. dollar obligation (or other currency) for a fixed-rate obligation in, for example, Canadian dollars.

For example, we are currently looking at exactly this type of approach to raise $10 million fixed-rate funds for a municipally-owned power company over a 13-year term. We are starting with floating rate U.S. dollars as the borrowing, which is converted to Canadian dollars and, through currency and interest swap contracts, ends up as being fixed-rate borrowing in Canadian dollars repayable in Canadian dollars with all costs known to the borrower.

What's the key thing to remember about swaps? They have brought financial markets around the world much closer together. They enable you to access other markets and other currencies without taking on additional risk/exposure in either interest rate or foreign currency movements.

Trends in the Domestic Market

The Province of Ontario, which is responsible for regulating stockbrokers who operate here, announced on December 4, 1986, that foreign companies, banks, and other institutions that had previously been barred from owning a brokerage firm or investment dealer will be free to do so starting June 30, 1987. The banks, of course, fall under federal regulation; however, on December 18, 1986, the federal government released its own white paper outlining plans for the financial services industry. It not only proposes to let banks into stock brokering, but also to knock down other regulatory barriers that prevent financial institutions from providing a full range of services. This is the "big bang" Bay Street is preparing for.

Banks are obviously pleased with these developments. The increased competition will be good for the customer. Certainly, it has been a source of some frustration for us to have the capability to provide a full range of investment banking services, and not be able to offer them to customers. Let us speculate for a few minutes about some of the things we might see in the years ahead:

- banks will become significant players in the securities industry as of 1987;
- banks will underwrite municipal debenture issues. As a future possibility, our retail branch network may be used to distribute debentures, to sell them to residents of your communities. We have been doing this for the federal government with Canadian savings bonds sales for many years; and
- municipalities may decide to distribute their own securities.

Changes in enabling legislation and some innovation would clear the way for new efficient means of financing, tax-exempt investments have been very popular in the U.S., and a prepaid tax bond would undoubtedly be very popular with investors in Canada. Securitization of revenue-earning projects could also tie specific cash flows to a financing for lower net costs.

CONCLUSION

The $14 billion needed to rehabilitate municipal infrastructure is a lot of money. To raise this amount will undoubtedly involve a substantial debt component. This, in turn, will challenge the financial officers of municipalities to use all the sophistication and professionalism at their disposal (and this includes outside advisors) to raise the funds in an increasingly complex domestic and global financing marketplace. To be cost-efficient, you must be able to access the cheapest funds wherever these may be available. This will require some minor regulatory change, and it will also mean closer relationships with the major financial institutions that are able to take you to the domestic and international financial markets.

THE REALITY OF MUNICIPAL FINANCING: WHY HAS PUBLIC WORKS LOST OUT IN RECENT YEARS?

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ABSTRACT

While the slice of the total financial pie allocated to urban infrastructure has been getting only marginally smaller in recent years, the need for additional expenditures has increased substantially. The primary causes for this financial shortfall include:

- changes in municipal funding priorities;
- the effects of increased public involvement in decision-making;
- a decline in the funds available from the provincial and federal governments;
- the increasing need for reconstruction and renewal;
- the rising cost of reconstruction and maintenance;
- lack of appropriate staff skills and data for problem analysis and infrastructure management.

Reference is made in this paper primarily to the Ottawa situation, although information pertaining to Canadian municipalities generally also is used. Concluding comments consider the question of whether the fact that public works has lost out in recent years is in reality a major municipal problem.

RÉSUMÉ

La part des affectations budgétaires consacrées à l'infrastructure urbaine a accusé une légère baisse au cours des dernières années, alors que le besoin d'augmenter ces dépenses s'est accentué considérablement.

Les principales causes de ce manque de fonds sont, entre autres:

- la modification des priorités municipales de financement;
- les effets de la participation accrue du public à la prise de décision;
- une diminution des fonds offerts par les gouvernements fédéral et provinciaux;

- le besoin croissant de reconstruire et de renouveler les infrastructures;
- l'augmentation des coûts de reconstruction et d'entretien
- le manque de personnel compétent et de données pertinentes pour l'analyse des problèmes et la question de l'infrastructure.

L'exposé porte surtout sur la situation d'Ottawa, mais il fait également appel à des données qui concernent les municipalités canadiennes en général. L'auteur se demande enfin si le fait que les travaux publics ont été perdants ces dernières années est vraiment un problème municipal de grande importance.

HAS PUBLIC W0RKS LOST OUT IN RECENT YEARS?

The deterioration of municipal infrastructure has been an issue of great concern to municipal officials in recent years. This concern led the Federation of Canadian Municipalities to commission a study in 1983 to provide an assessment of the situation in Canada. Response from larger municipalities, those over 100,000 population, was good (responses represented 77% of those living in such centres) and can be considered fairly reliable as a representation of the situation across the country. Conclusions from the study were that, "There is a significant municipal infrastructure problem in Canada. Such essential facilities as roads, sidewalks, bridges and sewers are in the poorest conditions and are deteriorating rather than improving", (l) and that, "Public works budgets, as a proportion of total municipal budgets have been declining. This is most evident in capital allocations for public works."(2)

When examining the situation in Ottawa, and determining what has happened over the last 15-year period (1971 to 1985), we found that we have experienced a similar situation, the portion of the total budget dollars allocated to infrastructure being reduced, while costs of construction continue to mount.

In Ottawa, the proportion of capital dollars devoted.to public works averaged 45.9% between 1971 and 1975, dropped to 35.5% between 1976 and 1980 and then to 28.9% between 1981 and 1985. This is a decline in percentage share of 17% of the total capital budget. Even the operating budget for public works has declined significantly by 14 % in this same period. It moved from an average of 33.8% between 1971 and 1975, to 23.2% between 1976 and 1980, and 19.7% between 1981 and 1985 (see Appendix 1). Although the bulk of actual construction costs is contained in the capital budget, this drop in the operating budget is significant because it signals the lack of priority given to the general upkeep of infrastructure which, in turn, causes more rapid deterioration and therefore compounds the already difficult problem.

I should mention here that reference to our public works or infrastructure budget is for items such as roads, sidewalks, sewers, and street-lighting. Services, such as water supply and filtration and sewage treatment, are provided by the Regional Municipality of Ottawa-Carleton.

Although the budget dollars allocated to public works have declined in real dollar terms and as a percentage share, our public works officials tell us that the need for additional dollars has not diminished.

Of our 692.4 kilometres of roads, 3.4% require immediate reconstruction, 13.9% in 1 to 5 years and 46.2% in 6 to10 years. The cost is estimated at $253.5 million. The approved quota of capital budget dollars for such work in 1986 was $2.2 million. (All information in this section supplied by the Department of Physical Environment, City of Ottawa.)

Of our 1457.9 kilometres of sewers, 268.3 kilometres are combined sewers. Much of this system is over 75 years old, constructed of a number of different materials and is rapidly reaching the end of its expected life span. Because of the problems now being experienced with this system, need for separation and upgrading at an estimated cost of $180 million is immediate. In addition, of the separated system, 6.6 kilometres are considered of immediate need of reconstruction, 25.6 kilometres of need of reconstruction in 10 years and 242.8 kilometers in 20 years, for a total estimated replacement cost of $110.8 million. The approved quota for all sewers in 1986 was in the order of $4 million. To keep up with the needs, approximately 4 times this amount is needed each year for the next 20 years.

With sidewalk reconstruction, the picture is slightly brighter. Of the 758.1 kilometres of sidewalk, 7.8 % are in need of reconstruction within 5 years for an estimated total of $6.4 million. The approved quota for 1986, however, was only $660,000.

There are at present approximately 18,400 street lights maintained in Ottawa. Additional lights are installed by request. Current requests total $1 million. The approved quota for 1986 was $500,000.

In addition to maintaining existing works at acceptable standards, the City of Ottawa faces continuing demands for additional sidewalks, ramps for handicapped persons, traffic control devices, elimination of drainage ditches and changes to underground wiring. There are also large price tags associated with these items which will further drain the already diminishing budget allocated to public works. For example, for just the construction of sewers in areas which now are drained by ditches, it would cost in the order of $70 million.

So, we appear to be in poor shape in terms of the municipal budget dollars available to meet the on-going need for public works projects. When the estimated costs for construction, reconstruction, and maintenance of infrastructure over the next 20 yearsare added up, we would need to put about $35 million a year into the capital budget, which is equivalent to our entire capital budget for 1985. Thus to meet the demand, we would need to devote almost the entire capital budget of the City of Ottawa to public works for the next 20 years - and possibly beyond. Obviously, this is an impossible situation.

WHY HAS PUBLIC WORKS LOST OUT?

So, what brought us to this point? What combination of factors has led to a situation as difficult as this? From our early analysis, there appear to be five areas of significant contribution:

- a shift in municipal funding priorities;
- the rise of public involvement in municipal processes;
- a decrease in funding provided by senior levels of government;
- a significant rise in the cost of construction, reconstruction, and maintenance; and
- a lack of success on the part of municipal staff in providing an overall analysis of the current state of infrastructure to convince politicians of the seriousness of the situation.

I would like briefly to touch on each of these with primary reference to the situation in Ottawa.

MUNICIPAL FUNDING PRIORITIES

If the money from municipal budgets for infrastructure has not been increasing or even remained constant, where has the money been going?

For both the operating and capital budgets, the story is similar. The budgets for general government and protection* have increased substantially over the 15-year period. In relation to the operating budget, these items have risen by approximately 13% from an average of 45% of the total City budget between 1971 and 1975, to an average of 58% between 1981 and 1985. The proportion of the capital budget rose by 19% from an average of 8% between 1971 and 1975, to an average of 27% between 1981 and 1985 (see Appendix 1).

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*General government covers corporate service departments such as Finance, Legal, Human Resources, City Clerk; management of some departments; and non-departmental items. Protection to persons and property includes Fire and Police protection as well as licencing and permits.

The increase in the budget for protection services has been engendered by a general concern for public safety, including protection of homes and businesses. This has resulted in large staff increases in fire and police departments and new structures to house employees and equipment, such as our fire station relocation program, renovating and renting office space for municipal staff and building a new police station. The largest percentage increase in general government services (operating budget) occurred in 1975, but there were also large increases from 1979 to1980 and from 1984 to 1985. The largest items in this budget are monies allocated to reserves and unforeseen expenditures. Much of this money is then diverted to projects or other accounts as necessary. However, some of the growth in this function also is due to an expansion of city programs and the resulting increase in the municipal staff complement.

Between 1971 and 1985, the total city staff complement grew by almost one-third from 2,992 to 3,938.(3) This reflected a change in municipal priorities and new expectations on the part of the public. In the 1970s, a general concern with quality of life, which emerged in the 1960s grew stronger, and along with it came the demand that higher service levels be provided by municipal governments. In this period, the greatest increases in municipal staff were in the fire and police forces, (part of which was due to taking on the work for another municipality), and the soft service or quality of life areas (recreation, planning, etc.).

In response to the public's desire to be consulted and informed, and the municipality's desire to reflect community concerns in its programs, a number of new programs were created while some departments expanded. This included staff to assist elected officials to serve the public better, staff to carry out council's policies related to Equal Opportunities, Bilingualism, and Public Participation and additional staff to service council and committees in their work. At the same time, staff responsible for public works remained stable in numbers.

PUBLIC INVOLVEMENT

In the 1970s, the public became increasingly more interested in projects that affected their immediate environment. Much of this was triggered by the disruption of older neighbourhoods by high-rise construction, but it was also a result of a general concern for the preservation of "quality of life" and protection of the environment. With the affluence of the 1960s and 1970s, people were interested in obtaining more and better municipal services. The traditional role of a local government was no longer considered adequate. Better roads and sewers alone were not of significant interest. Many of these services were fairly new and as long as cars moved and sewers worked - that is that maintenance was generally good - this was sufficient. With better economic times, what was of major concern were "soft" service items such as parks, community centres, pools, arenas, and recreation programs for children, and social and health programs for those in less fortunate circumstances. In addition, people increased their interest in their surrounding environment and their desire to protect it from disruption, pollution, overshadowing by larger structures, too much traffic, overcrowding, and intrusion of obnoxious or undesirable uses.

This increase in public concern led to increasing costs in a number of different ways. Some large public works projects had to be abandoned or modified. The Spadina Expressway may be the most famous example of this. People did not want neighbourhoods severed by expressways or excessive widening of existing streets. There was a growing concern that the car should no longer dictate the state of the neighbourhood. Other projects were delayed to allow for citizen input into the various stages of the process. This was particularly related to changes in recreation or leisure areas or new construction projects. At times, these delays meant that a project had to wait for another year before a new construction season started, because it was too late to be started in the present one. People also opposed large tax increases, which meant that the traditional less-interesting projects often got the "short end of the stick", while scarce municipal dollars were allocated to the "new" infrastructure (parks, community centres, arenas) and the programs associated with these. This type of infrastructure project was consistent with the desire to improve the general life style and ervironment of citizens.

In addition, in Ottawa, this lack of financial priority for traditional infrastructure projects was exacerbated by a change in policy which decreased the public's awareness of the mounting need to maintain and reconstruct basic infrastructure. Prior to 1977, Ottawa undertook public works under the provisions of the Local Improvement Act on the basis of petitions. High priority was assigned to the petition requests. The public generally knew what they wanted in their areas (new roads, sewers, sidewalks, street lights, etc.), were prepared to pay for them, and got involved in the decision-making process. Local improvement works had become heavily subsidized by the city, however, as the property owners' share of the cost of local improvements did not cover the total cost. Consequently, in 1976, it became apparent that council would either have to raise the property owners' share of the cost considerably, or change the way in which these public works projects were undertaken. Therefore, in 1977, council abolished the local improvement system. Subsequent public works (except for industrial subdivisions and, just recently, two commercial area projects) are now being completed as general works on the basis of technical "need" as established by our Physical Environment department.

With the advent of Ottawa undertaking all public works based on city-wide needs, the public basically has been excluded from the decision-making process and, consequently, is less aware of the upgrading needs that are required to keep our infrastructure operational. We have indeed conducted several area studies, but the focus has been on the provision of "soft" services (parks, recreation facilities, etc.). This is understandable because, after the tremendous growth in traditional public works in the 1960s and 1970s, the public turned its attention to other projects which would enhance the quality of life.

SENIOR GOVERNMENT FUNDING

"... post-war federal programs and contributions considerably alleviated the burden of financing major public works. Over the past 15 years, however, federal funding has declined steadily. In fact, as of March 1984, all direct federal assistance for municipal infrastructure ceased"(4).

During the 1960s, the City of Ottawa, in cooperation with the federal and provincial governments, attempted to resolve the city's problems in relation to the condition of existing of infrastructure and housing through the Urban Renewal Program. The approach of the Urban Renewal Program required that the city define areas of community improvement needs*, develop a plan for the identified area, expropriate existing land owners, demolish their properties, and build anew.

This program proved to be a very expensive financial proposition for the senior levels of government and, perhaps more significantly, it destroyed the fabric of the communities it was intended to assist. Consequently, the program was abandoned by the federal government and replaced, in 1973, with the Neighbourhood Improvement Program (NIP).

Under the NIP, substantial financial support from the federal and provincial governments was offered on a geographic basis for defined areas of need in the city. The senior levels of government required the city to prepare a rigorous analysis and both to validate and priorize its community improvement needs. Through the improvement of a neighbourhood's infrastructure (e.g. sewers, street lights, parks and community centres) and the rehabilitation of the existing housing stock, community improvement remained an important component of the city's planning and public works activities.

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* Community improvement may be very broadly defined as encompassing all those activities, both public and private, which conserve, develop and rehabilitate the existing physical environment to accommodate the social and economic priorities within the community. These activities have traditionally involved improvements, on an area basis, to the urban public infrastructure, i.e. roads, sidewalks, parks, community centres and housing.

The NIP was cancelled by the federal government in 1978 and replaced by the Community Services Contribution Program in 1979. The CSCP program was very similar to the NIP program, but was unilaterally cancelled by the federal government in 1981 due to budget restraint.

While initially a city, such as Ottawa, could expect senior levels of government to provide between 40 to 60% of the funds for these programs, after 1982, the availability of funds from senior levels decreased substantially.

Indeed, financial contributions from all levels of government for community and neighbourhood improvement programs have declined since 1979 (see Appendix 2). After 1982, only the Province and the municipality participated in community improvement through the Ontario Neighbourhood Improvement Program and the more recent Provincial Commercial Area Improvement Program. These programs represent the end of an era when many municipal community improvement efforts were dictated by senior governments.

In early 1984, the provincial government issued a directive to municipalities through the new Planning Act. The directive encouraged municipalities to take a more active role in community improvement and this directive has been acted upon by the City of Ottawa.

While the goals of these community improvement programs are laudable, the funds made available by any level of government were rarely sufficient to cover the costs really needed to renew roads and sewers. When shopping lists were put together for these programs, and it was found that even modest improvements to roads and sewers were likely to cost many more times the available funds, the lists often were forgotten.

As with the situation for community improvements, there was a time when more Provincial Road Subsidy (M.T.C.) money was available than municipalities could spend, but over the last 10 to 12 years, the subsidy allocation has been reduced so substantially that many Ontario municipalities must cover the entire cost of maintenance work which theoretically qualifies for a 50% provincial subsidy.

Due to the shortfall in the M.T.C. subsidy allocation, the City of Ottawa has on occasion, brought to the attention of the Minister of Transportation and Communications the considerable concerns that have arisen over the lack of an adequate initial road subsidy allocation and the need either to have this increased or to approve a supplementary allocation. The Minister usually replies by expressing his concern for the long-range condition of the City of Ottawa's road system and stating that the city can be sure that he will continually press for more funding for both provincial highways and the municipal road system. Until such funds actually are forthcoming, however, municipalities, such as Ottawa, must cover all costs with existing local funds.

In assessing reasons why public works has lost out in recent years, the historical attitude of senior government regarding the funding of the work, which they were prepared to subsidize, also deserves mention. Funding programs have habitually favoured new construction as opposed to regular maintenance and reconstruction. This, in turn, has influenced the City of Ottawa's approach and, I am sure, that of other municipalities. If senior levels subsidize 50% of new construction but 0% of maintenance costs, there is a natural tendency on the part of municipalities to stretch our already limited dollars by favouring items for which we can receive a subsidy. Therefore, while the decline in total funding from senior governments has been an important factor in reducing money available for public works, the programs themselves also contributed to the lack of attention to maintenance and reconstrucion. If, in the future, funding is once again restored in response to the severity of the problem, it is hoped that senior governments will recognize that the greater need to provide funds for maintenance and reconstruction projects is greater than that for new construction.

RISING COSTS OF RECONSTRUCTION AND MAINTENANCE

While funding from senior levels of government has been reduced substantially, the costs of reconstruction and maintenance have continued to escalate. While it is difficult to estimate the cost of reconstructing an "average" roadway for a city block (as there are great differences in length) it is estimated that a 600-foot city block, which cost $42,712 in 1975, cost the city $80,460 in 1985 (using 1975 dollars). This was an absolute increase in 10 years of 88.4% (see Appendix 3). The FCM study conducted in 1983 compared 1976 and 1983 costs and estimated that the expenditures for the total sewage collection budget rose from $8.08 to $15.48 per capita(5). In the same period, the total roads budget rose from $30.57 to $57.08 per capita(6). This is significant given the continued shortfall in municipal dollars allocated to infrastructure. Historically, the money available for maintenance over the years has been able to accomplish less and less each year, thus, the problem really has compounded exponentially. This problem becomes of even greater significance when coupled with the fact that deferred maintenance accelerates the deterioration of infrastructure, and requires much more extensive repairs than would have been necessary if proper attention were paid to maintenance regularly. The FCM study sums up this problem as it relates to roads by saying, "Knowing when to carry out specific types of preventative maintenance and rehabilitation is crucial to maintaining good roads at low costs. Deferred maintenance does not simply postpone today's maintenance costs but increases costs. The rate of pavement deterioration accelerates with time. The lowest annual maintenance costs are achieved when resurfacing is carried out before roads pass their lowest acceptable condition, i.e. before the point of incipient cracking."(7)

A related factor contributing to this rise in the cost of reconstruction and maintenance is the emergence of strict standards for the services. Ottawa has books of standards covering every aspect of building roads, sidewalks, sewers, and street lights, etc. Many of these standards are absolutely crucial to safeguard the public, but are they all? How many standards are set because of someone's best guess or at a level which can be described as a "Cadillac approach" rather than a "Volkswagon"? If municipalities can do something in a different, cheaper way and obtain generally similar results, should this not be possible? Perhaps we need to step back, recognize that the costs of upgrading public works to established standards over the next 20 years are astronomical and conclude that, other cheaper methods of safely moving people and goods and providing a healthy environment should be considered.

LACK OF PROBLEM ANALYSIS AND PROPER INFRASTRUCTURE MANAGEMENT

An additional reason why public works has lost out in recent years rests with municipal bureaucracy in that there has been a lack of appropriate problem-solving analysis and infrastructure management. There seems to have been in Ottawa, and I suspect in most municipalities, a historical lack of cost analysis or assessment of results implications in the formulation of the municipal budget. The traditional structure of municipal government and the nature of the political process have combined to exacerbate this problem. Separate departments, each pursuing its own aims, have discouraged a global or corporate assessment of appropriate funding priorities and the political ward system has emphasized lobbying for localized concerns.

As a result, virtually no mechanisms or systems exist to analyze the problem adequately. It is essential to identify clearly which budget areas are losing out and to identify the specific implications of continuing this scenario. Often one department has vied with another over the budget dollars available and relative success has depended, to a large extent, on the receptivity of the politicians.

Although our practitioners have made a valiant attempt over the last few years to take stock of the need for additional budget dollars, there has often been a problem with presentation:

- the dollar amounts quoted boggle the mind. How can we even begin to address needs when we are told that they are equivalent to the entire City capital budget of the city?
- often great sets of numbers and standards are brougnt out which can only be followed by someone who is familiar with their formulation;
- staff tell us what the problem is and how it can be solved, but often leave out why the problem came about and what precisely will happen if it is not corrected.

In some cases, dire warnings are issued even before the problem has been identified accurately, and proper equipment to synthesize and analyze the problem has been slow in coming.

All of these reasons create a disadvantage at budget time. The public can clearly see problems in a variety of municipal areas but for a problem such as deteriorating sewers, it is difficult for the public to favour maintenance of unseen sewers over maintenance of parks or community centres, or excessive time delays to get a building permit. In addition, the fact that our existing infrastructure is deteriorating has not been brought convincingly to the attention of the public. Proper economic analyses that would make the public aware of the implications of deferring these needs is difficult. Consequently, the needs of public works have been growing over the years while the funds to fill the need have been diminishing.

Considerable work is necessary both to present the problem properly, so that it will be heard, and to fit this problem into a corporate context. Ottawa has been working on both of these areas. Much effort has gone into the accurate identification of needs, and a process will soon be started to change the way we do work so as to emphasize the results we wish to achieve. At the corporate level, for the first time, our annual budget this year has been prepared on a functional basis. This will help us to begin looking at the relative amounts of money being put into each major area, rather than the previous traditional detailed line-by-line accounting approach to budgeting. As a result, we will begin to see the extent of the neglect of public works in the overall city budget, and begin to determine how this can best be addressed through the political decision-making process.

The advantage of our new approach is that we be able to begin to set meaningful priorities for the community, and to determine how best to address these over time. This is important for public works, as the funds required to rectify the problem must be allocated over many years. Only by clearly articulating the problem, and seeking meaningful solutions in terms of all possible funding sources, can we hope to make any substantial progress.

IS IT REASONABLE THAT PUBLIC WORKS HAS LOST OUT?

We have observed that public works has indeed lost out in terms of receiving municipal funds in recent years and have examined some of the factors which appear to have been main contributers to this situation. The question is, regardless of whether or not the present situation is of concern, has the past neglect been a reasonable response to circumstances? I would say that it has.

Much of the need for new infrastructure occurred during the 1950s and 1960s with the rapid expansion of urban areas and the move to the suburbs. For instance, in Ottawa between 1874 and 1950, 232 miles of sewer were built while, from 1951 to1961, 335 additional miles were built (see Appendix 4). Since 1971, the total population of Ottawa has not grown (see Appendix 5) and the type of development which took place in the last 25 years has been primarily apartment and infill construction. In Ottawa, of 46,572 units created from 1971 to 1985, 32,913 or 70% were apartment units (see Appendix 5). This type of construction often has not necessitated changes in the sewer system and only required minor changes in the road network. Even when additional services were required, the developer, then ultimately, the renter or buyer, absorbed the costs. Thus, there has been little need to increase the public works part of the budget greatly to expand services in recent years.

Since municipal officials have often been unable to articulate clearly the precise repercussions of postponing maintenance work for existing infrastructure, it has been difficult for politicians to deny the insistent demands of a public interested in improving the quality of the visible municipal environment through the provision of more "soft" services. For the public, it was questions of: "If the sewer doesn't back up, is maintenance a problem?" and "Do I care more about the sewer's possible state of repair in 10 years than I do about not having a park for my children to play in now?"

Although the FCM study indicates that a good portion of public works facilities require some repairs, only roads and sidewalks exceeded a 10% level in terms of requiring much repair (see Appendix 6). In other words, there is no evidence from the study that facilities are at present in wide-scale need of major reconstruction. Accident statistics are not up at an alarming rate as a result of poor roads. In fact, in Ottawa, accident statistics between 1971 and 1985 have remained quite stable (see Appendix 7) while the number of cars has escalated. There is much more evidence of motorist annoyance that so much road maintenance goes on each summer. Although there may be pockets of evidence of sewer damage (sewer backups at times of flooding), this is a phenomenon which has occurred within a relatively restricted area of the city. Therefore, although there is cause for future concern, because many roads and sewers were built between 1950 to 1960 and may experience major deterioration at the same time, it is a fairly natural response to concentrate on immediate visible concerns rather than problems in an unknown future.

Another issue which municipal officials should consider is the total public support of all aspects of "moving vehicles and people safely" and "providing a good quality pollution-free environment". We may need to look collectively at just what the entire public sector, including all levels of government, have attempted to achieve in the public works area and how we have gone about achieving this. Municipal public works contributes only a portion of services to achieve the goal of "moving people and goods safely and efficiently".

For instance, in the 1970s, when people were very concerned with the quality of the environment and rising energy costs, a conscious decision in many urban areas was made to increase the use of public transit rather than put money into roads. Objectives at this point included "reducing pollution", "helping to alleviate congestion on roads" and "reducing the need for large areas of expensive land to be devoted to parking lots". As a result, substantial sums from the public purse were diverted to transit. In Ottawa, between 1971 and 1985, the annual reports for the Ottawa-Carleton Regional Transit Authority show that the amount of subsidy required to eliminate the annual deficit rose steadily from $803,308 in 1971 to $58,888,000 in 1985.(8) This indicates a considerable increase in public support over the 25-year period. Also, in Ottawa, the municipal public works budget does not take into account the large sums of public money spent on regional roads, roads and bridges of the National Capital Commission, the major east-west carriers such as the Queensway and the Ottawa River Parkway, major sewer treatment facilities, etc. Granted, services looked after by these other bodies may be fewer in other municipalities, but the principle still rings true that we need to look at overall public priorities and the contributions of all levels of government when we consider whether the decline in the public work portion of the municipal budget is reasonable.

LEARNING FROM THE PAST

Public works officials need to recognize that there have been some legitimate reasons for neglecting public works somewhat in favour of other municipal services in recent years. Other areas did require priority and, in essence, politicians on behalf of the public have a right to determine where priorities should lie. It is important that the warning bell has been rung and the detailing of the extent of the problem has started in time to address it in a more meaningful way. However, given the extent of the costs, this also needs to be coupled with a hard look at the expert's side of the issue. Are public works officials being totally responsible in outlining such a dark picture of the situation and the dollars needed to solve it? For example, must we absorb the costs of meeting all of our infrastructure standards? Are they all really necessary or could we settle for less? What essentially are we trying to achieve through our various public works policies and programs and are these objectives consistent? What is the real extent of the work we must undertake when we separate out the projects which "would be nice" from those which are "absolutely essential for public safety"? And, what exactly will happen if we can't find the money to correct the problems?

These questions require answers because public works is not the only service area which will cost taxpayers large sums to maintain in the future. We have increasing costs for maintenance of recreation and community facilities. Larger numbers of the population are out of work or on subsistence incomes.

This segment of the population, in addition to potential job prospects, has need of a variety of social services and housing. Are roads without potholes more important than economic development projects or providing shelter and clothing for those who cannot afford them? Do we let our community centres and parks become dilapidated before our sidewalks or sewers? These and other difficult questions will be facing politicians in the future just as they have in recent years. They are trying to make good decisions, to balance distribution of municipal budget dollars and to keep our citizens happy. If you feel a crisis in public works financing is at hand, which indeed appears to be the case, the questions of concern now are how to convince the politicians and the public that the large sums of money quoted as being necessaryto rectify the problem are totally justified, and whether the implications of not addressing this crisis fully are more severe than the implications of not addressing the other municipal budget demands.

Useful lessons can be learned from the reasons why public works has lost out in recent years. To avoid repeating them, the focus should be placed on four areas.

The first is to refine the measurement tools used to determine the exact extent of the problem. Often, when the tools are not as accurate as we would like, we overemphasize the problem to make sure it is covered. We cannot afford to do this; when the estimated costs sometimes have become too overwhelming to handle, it is often human nature to back away from the problem.

Second, once we have a better idea of the exact extent of our needs, public works officials need to establish credibility with politicians and the public. This includes demystifying the situation and the standards used. The problems must be explained in a way which lay people can understand and begin to address.

Third, there should be greater involvement of local people who will be affected. In Ottawa, we have learned what happens when people are removedfrom the decision-making process and we are reconsidering the use of local improvement charges.

Fourth and last, we need to pay attention to the formulation of a rational funding plan. We can't just confront people with the enormous costs of bringing all of our infrastructure to acceptable standards. We need to break this up into phases and begin to address concrete alternatives for finding the dollars required. We may need to explore innovative financing schemes extensively because a sharp increase in property tax is never a welcome alternative.

These steps will not erase the fact that there are other major demands for municipal dollars, but they may go a long way to ensuring that this particular demand is fully understood and appreciated and steps to alleviate the problem are readily at hand.

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Appendix 1

PUBLIC WORKS - PERCENTAGE SHARE OF MUNICIPAL BUDGET, 1971-1985

TOTAL BUDGET

	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
General Government	14.8	17.7	13.4	14.5	18.9	19.2	17.2	20.0	19.5	23.2	23.8	21.2	19.5	20.4	23.2
Protection	20.4	20.7	22.1	21.7	21.2	23.0	23.8	24.7	29.1	26.6	29.9	27.5	31.9	32.6	32.4
Public Works	34.9	39.0	39.9	39.2	28.5	28.2	23.0	27.4	26.5	22.1	21.2	20.8	21.6	21.3	21.3
Social Services	1.4	1.5	1.8	2.1	2.3	2.5	1.8	4.1	3.0	2.0	1.8	1.8	1.2	1.2	1.2
Recreation & Culture	21.5	13.9	15.9	15.5	15.2	17.3	20.4	18.0	17.0	14.4	18.8	15.4	18.7	18.7	16.6
Planning	7.1	7.2	7.0	7.0	13.9	8.5	13.7	5.8	4.9	11.7	4.4	13.4	7.2	5.7	5.4

OPERATING BUDGET

	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
General Government	17.8	19.9	15.6	17.8	24.6	23.5	21.5	21.9	21.8	27.6	26.5	24.2	21.1	21.2	24.0
Protection	26.6	26.0	26.5	25.1	26.4	28.2	28.7	28.5	30.1	28.3	31.9	34.2	36.3	35.4	34.8
Public Works	34.0	35.6	36.1	36.5	27.0	25.8	22.5	23.9	23.6	20.4	18.6	18.7	20.6	20.8	19.7
Social Services	1.9	1.8	2.2	2.6	3.0	3.1	2.4	4.8	3.7	2.5	2.2	2.2	1.4	1.4	1.3
Recreation & Culture	15.9	13.3	15.3	14.4	16.3	16.7	19.7	16.9	17.5	16.9	16.9	16.9	17.0	16.9	15.7
Planning	3.8	3.5	4.3	3.7	2.7	2.8	5.1	4.0	3.3	4.3	3.8	3.8	3.6	4.2	4.4

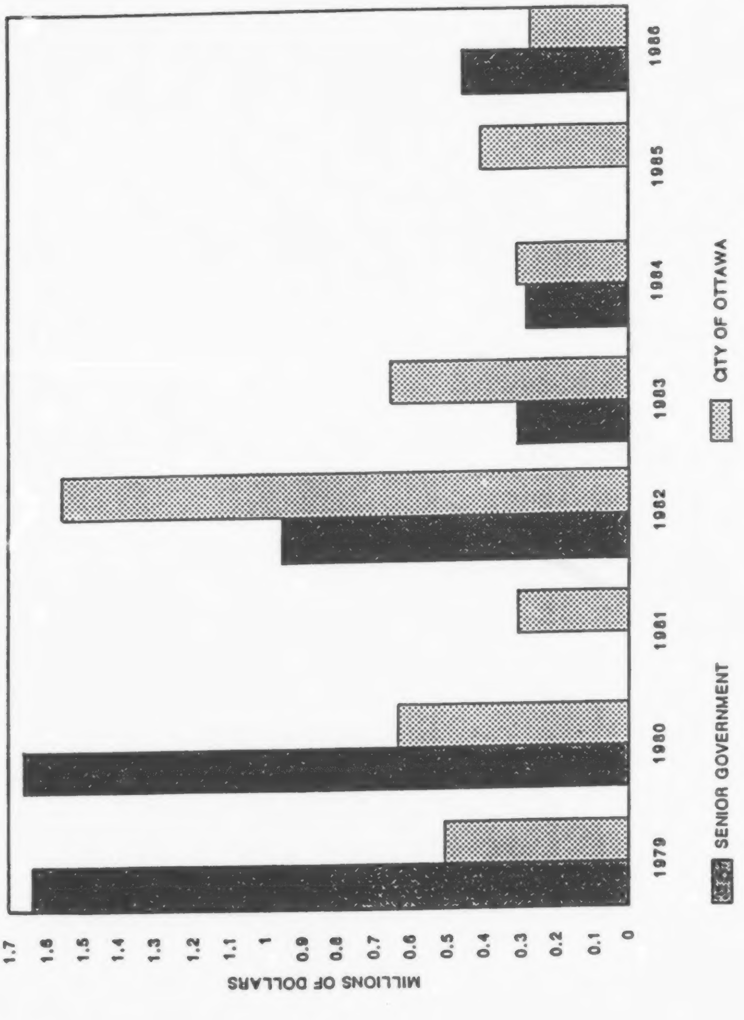
CAPITAL BUDGET

	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
General Government	6.5	9.1	4.2	0.9	0.5	0.6	3.9	9.7	9.0	8.2	11.0	9.7	11.8	15.9	17.9
Protection	3.7	.8	2.4	7.4	4.6	0.9	8.9	3.4	24.6	20.7	20.4	2.5	11.3	16.6	17.6
Public Works	37.2	51.9	56.3	50.8	33.2	38.4	24.5	46.9	39.6	27.9	33.7	28.9	26.2	24.3	31.6
Social Services	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Recreation & Culture	36.6	16.4	18.1	20.1	11.5	20.1	22.5	24.0	14.6	5.6	27.6	9.5	26.5	28.8	21.9
Planning	16.0	21.7	19.0	20.8	50.0	33.0	40.0	16.0	12.2	37.6	7.3	49.5	24.1	14.2	11.1

Appendix 2

COMMUNITY IMPROVEMENT FUNDING 1979 – 1986

SENIOR GOVERNMENT AND CITY CONTRIBUTIONS



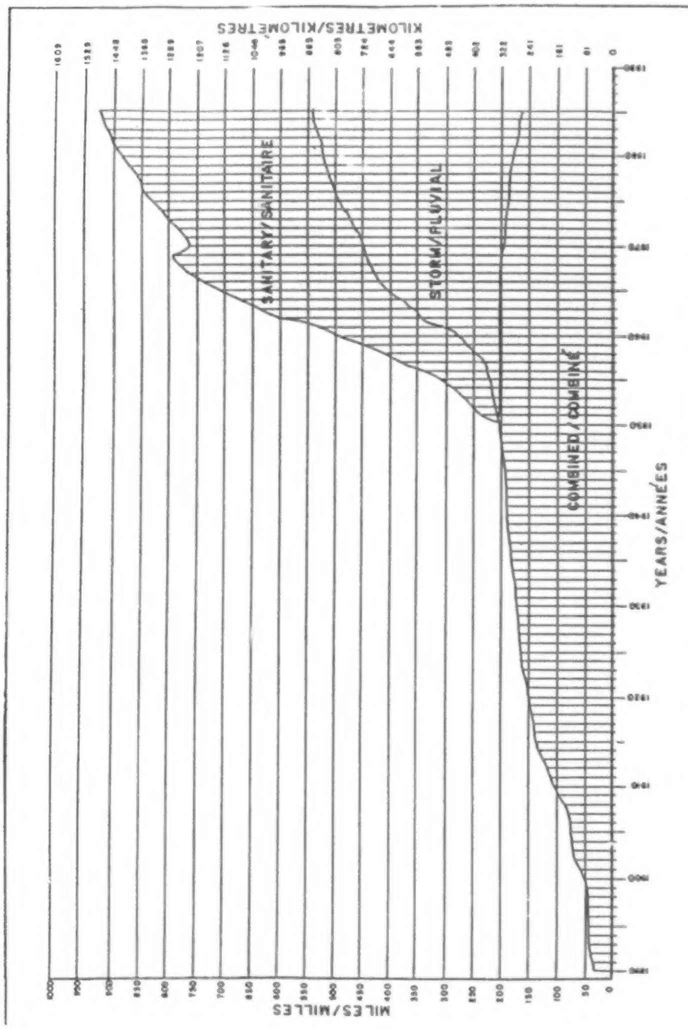
APPENDIX 3

ESTIMATED COST OF RECONSTRUCTING A RESIDENTIAL ROADWAY. 1975-1985

Estimated cost to reconstruct a residential roadway with curbs in 1985 was $440/m ($134.10/ft or $80,460/600 ft. City Block). Using the Price Index information received from the MTC for estimating "Highway Costs Excluding Municipal Works", the following figures are estimated:

YEAR	MTC INDEX	DOLLARS per CITY BLOCK (600 ft.)
1975	150.6	42,712
1976	161.3	45,746
1977	176.2	49,972
1978	192.9	54,708
1979	204.5	57,998
1980	221.5	62,819
1981	259.7	73,653
1982	271.0	76,858
1983	267.6	75,894
1984	277.6	78,730
1985	283.7	80,460

From this table, it can be seen that the cost of re-constructing a 60-foot city block rose from $42,712 in 1975 to $80,460 in 1985, an increase of 88.4 %.



GROWTH OF CITY OF OTTAWA SEWER SYSTEM / CROISSANCE DU SYSTÈME D'EGOUT / VILLE D'OTTAWA

TOTAL MILEAGE TO DATE / DISTANCE TOTAL = 929·903 miles, 1496·465 km.

APPENDIX 5

TOTAL POPULATION, CITY OF OTTAWA. 1971-1985

YEAR	POPULATION
1971	302.355
1976	304.450
1981	295.175
1985	303,617

Source: 1971, 1976, 1981 Statistics Canada
1985 City of Ottawa Assessment Records

TOTAL HOUSING UNITS CREATED
CITY OF OTTAWA. 1971-1985

YEAR	TOTAL UNITS	APARTMENT UNITS
1971	5,299	3,664
1972	7,209	6,050
1973	9,788	8,839
1974	4,351	3,920
1975	1,154	552
1976	2,065 .	740
1977	2,122	1,476
1978	2,297	1,321
1979	1,147	489
1980	1,235	649
1981	1,326	401
1982	1,917	920
1983	2,374	1,251
1984	1,893	1,148
1985	2,395	1,493

Source: City of Ottawa Building Permits

Summary of Infrastructure Condition and Budget Priority (population weighted response).

Population of 8,855,187	Age		Present Condition						Budget Priority					Change in Condition		
FACILITY	Resp.	Ave. Age	Resp.	Good	OK	Some Rep.	Much Rep.	No Good	N/A	Resp.	1st	2nd	3rd	Resp.	Better	Same	Worse
Water Treat.	80%	21	94%	54%	29%	4%	7%	1%	5%	56%	30%	12%	15%	82%	61%	18%	3%
Water Dist.	77%	28	95%	45%	20%	20%	4%	7%	3%	68%	27%	21%	20%	83%	54%	15%	14%
Sewage Coll.	81%	30	95%	27%	12%	48%	6%	0%	2%	72%	24%	25%	24%	83%	32%	37%	15%
Sewage Treat.	76%	15	89%	40%	10%	37%	1%	1%	8%	75%	62%	2%	10%	77%	64%	12%	1%
Storm Sewers	80%	20	95%	21%	39%	29%	3%	3%	1%	71%	21%	20%	21%	85%	44%	37%	4%
Roads	76%	23	96%	5%	22%	41%	27%	0%	1%	73%	30%	25%	18%	96%	24%	24%	48%
Sidewalks	72%	17	92%	0%	28%	40%	16%	0%	6%	59%	15%	14%	30%	90%	27%	35%	27%
Bridges	71%	22	81%	8%	26%	45%	1%	0%	6%	61%	20%	12%	29%	80%	38%	22%	20%
Traf. Control	73%	9	79%	44%	16%	10%	1%	0%	7%	47%	15%	16%	18%	59%	45%	14%	1%
Transit	27%	7	29%	13%	9%	0%	7%	0%	58%	28%	0%	19%	8%	29%	20%	1%	8%
Solid Waste	71%	10	74%	35%	11%	28%	0%	1%	13%	70%	17%	49%	4%	74%	48%	18%	8%
Pub. Bldgs.	66%	20	71%	25%	27%	10%	7%	2%	15%	59%	2%	31%	26%	69%	40%	27%	2%
Park/Rec.	59%	15	68%	21%	25%	20%	1%	0%	18%	58%	7%	14%	38%	67%	27%	38%	2%
Cultural	34%	20	36%	19%	5%	8%	3%	1%	50%	27%	2%	6%	21%	37%	22%	8%	7%
Soc. Services	44%	15	48%	24%	19%	5%	0%	0%	39%	39%	0%	5%	34%	47%	32%	16%	0%
Others	1%	28	1%	0%	0%	0%	0%	0%	87%	1%	0%	0%	0%	1%	0%	0%	0%

Table 2. Per Capita Municipal Budgets (in dollars of day).

	Total Survey of 71 Municipalities					
Population	Dollars per Capita (Responses)			Percent of Total		
8,855,187	1968	1976	1983	1968	1976	1983
Total Budget	$263	$571	$955	100.0%	100.0%	100.0%
Pub. Wks. Budget	$ 84	$143	$248	31.9%	24.9%	26.0%
Total Operating	$203 (44)	$412 (55)	$760 (69)	77.1%	72.1%	79.5%
Pub. Wks. Operating	$ 43 (43)	$ 77 (54)	$147 (67)	16.3%	13.5%	15.4%
Total Capital	$ 59 (39)	$158 (51)	$193 (65)	22.4%	27.7%	20.2%
Pub. Wks. Capital	$ 41 (37)	$ 65 (49)	$101 (65)	15.6%	11.4%	10.6%
Debt	$ 23 (32)	$ 31 (45)	$ 70 (57)	8.9%	5.5%	7.3%

Source: Adams, B.J. and Heinke, G. W., 'Canada's Urban Infrastructure: Rehabilitation Needs and Approaches'.

APPENDIX 7

ACCIDENT STATISTICS
CITY OF OTTAWA
1971-19B5

YEAR	NUMBER OF REPORTED ACCIDENTS
1971	6,806
1972	10,005 (1)
1973	9,565
1974	10,562
1975	10,796
1976	10,774
1977	10,020
1978	8,574 (2)
1979	8,953
1980	9,683
1981	9,734
1982	10,252
1983	10,721
1984	11,149
1985	10,235 (3)

Source: Regional Municipality of Ottawa-Carleton, Transportation Planning Department

(1) Increase in accidents reported due to introduction of standard motor vehicle form

(2) "Reportable" level raised from $200 to $400

(3) "Reportable" level raised from $400 to $700

INFRASTRUCTURE INVESTMENT AND ECONOMIC GROWTH

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ABSTRACT

Considering that there are likely to be unemployed human and capital resources available to the economy in the later years of this decade and on into the next, a large addition to infrastructure-spending would add to national income and employment.

The magnitude of this addition depends on how the program is funded. If financed solely through debt, a $14-billion, 5-year program would generate 285,000 person-years of employment, or between 45,000 and 60,000 annually. If financed through increased user fees and taxes, and if there were upward pressures on interest rates, the employment impact would be reduced to about 220,000 person-years over the 5-year period.

In selling the idea of such an investment to governments, it must be recognized that governmental debt loads are already high, and in the case of the federal government, are likely to continue to grow in the coming years. While provincial and municipal debt loads are likely to be less severe, they nevertheless are likely to run combined deficits of $4 to 5 billion annually.

In addition, the federal and provincial governments will likely point out to municipal governments that they have taken an increasing share of the national income in the last decade, and that financing of capital expenditures could come from reduced growth or cutbacks in current municipal expenditures. If financed in this fashion, the net effect on employment would likely be even smaller than indicated above.

RÉSUMÉ

Étant donné qu'il y aura vraisemblablement des ressources humaines et financières disponibles vers la fin des années 80 et au début des années 90, on

pourrait relever le revenu national et le nombre d'emplois en augmentant les dépenses relatives aux infrastructures.

L'importance de cet ajout au revenu et au nombre d'emplois dépendrait de la façon dont le programme serait financé. Si le financement provenait uniquement d'emprunts, un programme supposant des dépenses de 14 milliards de dollars en cinq ans ajouterait 285,000 années-personnes au taux d'emploi ou environ 45,000 années-personnes par année. Si, par contre, le financement se faisait par une hausse des taxes et droits versés par les utilisateurs et si les taux d'intérêt avaient tendance à augmenter, le nombre d'emplois créés serait ramené à environ 220,000 années-personnes au cours des cinq années.

Or, pour vendre l'idée d'un tel placement aux gouvernements, il faut d'abord admettre que la dette des gouvernements est déjà élevée et que, dans le cas du gouvernement fédéral, elle continuera vraisemblablement de s'accroître au cours des prochaines années. Part ailleurs, bien que les dettes des provinces et des municipalités sont varisemblablement moins onéreuses, elles représentent néanmoins un déficit global estimatif de 4 à 5 milliards de dollars par année.

De plus, il se pourrait bien que les gouvernements fédéral et provinciaux fassent remarquer aux administrations municipales qu'elles ont bénéficié d'une part croissante du revenu national ces dix dernières années et qu'il leur serait possible de financer des dépenses d'immobilisations en n'augmentant pas leurs depenses municipales aussi rapidement ou en coupant leurs dépenses actuelles. Si le programme entrepris était financé de la sorte, son incidence nette sur le taux d'emploi serait alors sans doute encore moins importante qu'on ne l'indique ci-dessus

A MAJOR INITIATIVE FOR NEW SPENDING ON MUNICIPAL INFRASTRUCTURE

The precise magnitude of the infrastructure deficiency may be open to question, but some attempts at measuring it have been made. As early as 1984, the Federation of Canadian Municipalities (FCM) undertook a survey that established, to their satisfaction, that a significant deficiency existed.

From this information base, it was deduced that the gap could be closed with an expenditure program of about $12 billion, costed at the prices of the survey year: 1984. Under the assumption that the program would be implemented from 1986 to 1990, this figure was inflated to $14 billion to reflect the fact that prices rise from year to year. Since the program has not yet begun, the current dollar figure would be even higher, say $16 billion, if the program is implemented from 1988 to 1992.

Given this starting point, the FCM asked my company to assess the full economic impact of doing something about the deterioration. Today, I want to provide

you with a summary of the impacts that according to our analysis, such a program would have on the general economy. But both the size of the impacts and the probability of the program gaining support depends on its funding; accordingly, I also want to raise considerations that I think are relevant to that.

ECONOMIC IMPACTS

To measure the economic effects of a major spending program, we start with a base-line projection of economic activity that presumes that only "normal" capital spending occurs. This is then compared to a projection that assumes that the program occurs. The difference between the two projections measures the economic impact of the program.

In particular, we assumed the program would be spread over 5 years, with each of the three levels of government funding one-third. In one variant of this, we presumed that the program was funded solely through debt and that there was no effect on interest rates; in another, we presumed that municipal governments would raise user fees and local taxes to fund the program from current revenues, and that additional capital requirements of the federal and provincial governments would cause a small increase in interest rates generally.

Considering that the country will almost certainly have unemployed labour resources available over the last half of the 1980s, we concluded that there would be a positive impact on economic output, employment, and incomes in each year of any spending program. The magnitude of these effects varies, however, depending on how the program is funded.

If funded through increased taxes and user fees at the municipal level, and if increased federal and provincial borrowing increases interest rates, then real economic activity would be increased by roughly the size of the program only. Higher interest rates and reduced household incomes that follow from increased taxes and user fees would reduce consumer expenditures and investment by business, thereby offsetting any indirect positive effects of the construction program on the economy. The impact on the general economy could be even smaller. This would occur if the program is also paid for by restricting the growth of municipal current expenditures (i.e., by reducing or slowing the growth of municipal or school employment or wages), or by reducing other federal or provincial expenditures.

At the other extreme, if the program is funded completely by debt, and there are no adverse impacts on interest rates, real economic activity would be increased by more than the initial expenditure. This multiplier effect reflects the indirect benefits to downstream and upstream suppliers, and increased investor, and consumer-spending induced by higher wage and corporate incomes.

For an infrastructure program partly funded through increased taxes and user fees, and with some upward pressure on interest rates, we judge that total economic activity would be increased by a little less than 0.5%, yielding a cumulative employment impact for the 5 years of 220,000 person-years or a little less than 50,000 each year. The construction and durables manufacturing industries would benefit most from the program. Construction employment would increase by about 10,000 person-years initially, rising to 20,000 annually in the last 3 spending years. While local pressures on labour and materials may lead to upward pressure on wage rates and material prices, the size of the program is small in the context of the total construction program, and we do not think it would have a significant general inflationary influence.

If the program is funded solely by debt and there are no adverse consequences on the interest rate, the 5-year benefits would be higher, by as much as 285,000 additional person-years of employment.

A larger economy would increase government revenues and reduce some expenditures, and thus governments could expect to recover some of the initial spending. Nevertheless, there would be a negative effect of about $6 billion (at current prices) on the combined balances of all governments. In the event that each government funds its share of the program through debt and there is no adverse effect on interest rates, we anticipate that the effects on federal and provincial balances would be neutral. In contrast, the deterioration in municipal balances would average more than $1 billion annually. In the event that municipalities fund most of their share through increased taxes and user fees, their balances would be positively affected. As I have outlined, this would weaken the general economic benefits of the program, and if higher interest rates also occur, there would be a deterioration in the balances of federal and provincial governments.

FUNDING CONSIDERATIONS

Whether the infrastructure program gains support depends partly on how attractive this is to politicians looking for "job-generating" programs. However, the state of government finances over the next 5 years, as well as governmental expectations about the impact of the program on their financial picture, also will be significant.

Governments at all levels have exercised restraint since the mid-1970s in at least one sense: growth of real expenditures has decelerated. Counting both current and capital spending at all levels, growth has averaged 1.2% since 1974. Reflecting this, capital-spending by provinces and municipalities has remained essentially unchanged since 1975. This fact is another indicator that a real "gap" is emerging. Nevertheless, the affliction of a debt that rises more quickly than economic activity, an increasing problem for the federal government, also has begun to become a problem for provincial and municipal governments.

Even if one anticipates that the restraint that has been exercised in recent years is carried forward, the federal government will continue to experience a rise in its debt-to-GNP ratio. The problem for the provinces and municipalities is less severe and may ease somewhat in the next several years. Nevertheless, it is likely that the provinces,, taken as a group, will continue to run deficits in the range of $2 to 3 billion.

This is going to make it difficult to carry the day with calls for additional spending, no matter how much merit in the "deficiency" case, or how politically attractive it might be. And given the relative fiscal difficulties of various governments, it is reasonable to suppose consideration of an expanded infrastructure program undertaken at the expense of other current expenses of government. Since the wage bill of governments constitutes the largest component, such pressure would have to fall most heavily in that area. That will make for some difficult choices.

The growth in the number of government employees has been fairly restrained since 1975, about 1% annually. Reduction in the size of bureaucracies is difficult because it implies a reduction in services available to business, households, and special interest groups in communities. There may be opportunities, however, for restraint in the growth of government wage rates. On average, public sector wage rates have grown more rapidly than those of other wage earners, by 1.5% annually since the mid-1960s. Wage rates in the schools have grown 3% more rapidly than those of others over the same time frame. Restraint on the wage rate side would run into resistance from public sector unions, and it may be difficult to sell the idea of using savings generated by wage rate restraint on school teachers or municipal employees (who provide assistance to the infirm and aged, for example) as the basis for funding improved streets, sidewalks, highways, etc.

Finally, it is important to recall that funding an infrastructure program fully through spending reductions in other areas will imply little positive impact on overall economic activity. It would lead to a positive impact on construction and manufacture of durables, but reduced activity in other areas.

ESTABLISHING THE DEFICIENCY CASE

The second pillar of support for additional expenditures will have to be the merits of the deficiency case itself. By itself, job generation should have little weight, since increased expenditures for social housing, day care centres, increased pollution controls, and a stronger defence establishment will also generate additional jobs. You should be aware that the groups that stand behind each of these interests have also prepared a macro-economic impact statement and use these results to carry their case with the politicians.

And remember that the "deficiency" argument is a tough one. It is not sufficient to establish that there is a gap. It is important to establish that the infrastructure gap is more important than the social housing, pollution, or defence gap. Or, to be more positive, the case can be made that since we have unemployed resources, an attack can be made on all of these deficiencies.

WILL IT HAPPEN?

Despite all of the financing and difficulties in choice so far outlined, I suspect we will see a program of some kind. You can be assured that there will some period of slow economic growth within the next few years. Government capital projects are a favorite contra-cyclical tool to deal with such events. You may all recall that the federal government used this a few years ago in the form of the Special Capital Recovery Program.

Further, it does not hurt prospects that municipal authorities have been promoting this for several years. That has to be a formidable sales force. And if you have to pick a date when it will start, you might consider when the next federal election will occur. In short, the message to the city engineers is: keep those projects well designed and "on the shelf".

THE CHALLENGE OF CREATING PUBLIC AWARENESS

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ABSTRACT

To convey their message to the news media, those seeking to build public support for repairing urban infrastructure should not sit back and wait for reporters, who are preoccupied with other matters, to come to them.

There are several ways to dramatize the need for initiating broad repairs. These include:

- use of press conferences at the site of hazardously deteriorating bridges, highways, watermains, etc.;
- visits to newspaper editorial boards to sensitize opinion leaders to objectives; and
- appearances on hot-line shows and the like when, for example, annoying road repairs begin, to make the public understand the need for such work and to know what is being done to minimize inconvenience.

To get public support, those in charge of infrastructure repairs have a responsibility to insist on the cooperation of non-repair agencies, including the police, to ensure that everything possible is being done to reduce inconvenience, which often is not the case.

RÉSUMÉ

Ceux qui cherchent à rallier l'appui du public pour faire réparer l'infrastructure urbaine ne doivent pas attendre que les journalistes - qui sont préoccupés par d'autres choses - viennent à eux, pour transmettre leur message aux medias.

Il y a plusieurs façons de frapper l'imagination pour faire saisir la nécessité d'entreprendre des travaux de réfection générale. On peut:

- convoquer des conférences de presse sur le site de ponts, de routes, de canalisations d'eau, etc. dont la détérioration présente un danger;
- rendre visite au conseil de rédaction du journal pour sensibiliser les dirigeants de l'opinion publique à ses objectifs;
- participer à des tribunes téléphoniques ou à d'autres émissions semblables au moment d'entreprendre d'ennuyeux travaux de réparation routière, par exemple, afin de faire comprendre le nécessité de ces travaux à la population et de lui faire savoir les moyens qui ont été pris pour causer le moins de dérangements possible.

Pour rallier l'appui du public, les responsables de la réfection de l'infrastructure se doivent d'insister sur la collaboration des organismes qui ne participent pas à la réfection, notamment à celle du service de sûreté, afin de s'assurer qu'on fait l'impossible pour diminuer les dérangements occasionnés, ce qui, malheureusement, n'est souvent pas le cas.

What can you, as persons involved in repairing the urban infrastructure, do to get more media attention for your cause (and hence generate public pressure on politicians for more financing for your cause)?

As a journalist, it's not my job to dispense public-relations advice. But as a journalist it is my job is to make sure that newsworthy events or opinions, that is, developments that are of legitimate public interest, find their way into the press. Any member of the public has a right to know what steps to take in approaching the media. It is unfortunate that for outsiders, this often seems to be a bafflingly complicated, and frustrating experience. So let me give just a few quick tips.

First, here is what not to do.

Do not send out a press release on the need for more attention to roads or sewers and then sit back and wait for the media to come running to your press conference. The media is habitually understaffed and preoccupied with breaking news events, and press releases on ostensibly dull subjects are likely to be ignored or, at best, to get modest space back with the truss ads.

So the first rule is: Do not be passive.

So what do you do?

Here are three ideas.

Number one: Prepare the ground work carefully. Cultivate opinion leaders in the media. I am thinking in particular of newspaper editorial boards, those anonymous people (I am one of them) who write unsigned editorials.

In recent years it has become quite common for politicians, ranking civil servants, and leaders of outside pressure groups to ask to come in and chat informally with editorial boards. At my paper, for example, in the last few months we have had Pat Carney, the federal energy minister, come in to give her side of the story about her controversial softwood-lumber pact; leaders of the Montreal Chamber of Commerce to tell us why the federal government should cease sending commercial flights to Mirabel Airport; environmentalists to tell us why the City of Montreal should not build a tower on Mt. Royal; and a South African diplomat to challenge our views on his country. What is true for us is true of most editorial boards around North America.

If a group of engineers or other persons concerned about the crumbling urban infrastructure want to alert an editorial board of the importance of their concerns, most newspapers would likely welcome a delegation. They might or might not be impressed with your arguments, and they might or might not write editorials supporting your position, but you would have succeeded in making your position known. With luck, sensitizing an editorial board to your concerns can have a twofold effect: It can generate editorial coverage, and it can lead to more news coverage.

Let me explain how newspapers work. Those who write editorials are quite distinct from those who write and edit regular news stories; they are seldom the same people, and there are often subtle rivalries between the two staffs. But there is communication between them, and if an editorial-writing staff is convinced of the importance of a given issue there is a good chance this interest will have the spin-off effect of generating more coverage in the news pages. Moreover, television and radio journalists often get much of their sense of what is newsworthy from the print media so you have a good chance of reaching those areas of the media this way as well.

A question of mechanics: How do you know whom to call to set up a meeting with an editorial board?

Don't call the publisher or editor-in-chief or managing editor. Call the editorial-page editor. You can get his or her name from the masthead, which in most papers is found either on the editorial page or page 2. You don't need to hire a public relations consultant to do this for you. Besides, most senior journalists prefer dealing with the person in charge rather than with a flack. So Step No. 1 is: don't be shy. Invite yourself to an editorial board.

The second step is to be creative in generating follow-up media interest.

Let me give you an example of what I mean. Last month there was an incident on one of Montreal's major bridges, the Jacques Cartier Bridge. A one-metre chunk of its surface simply dropped out. Fortunately, the chunk did not land on any ship and no car fell into the hole. But the story was only one-and-a-half inches long in my paper. Why? Well, the only official who commented was the general manager of the federal agency that operated the bridge and what he said was predictable: "An isolated incident." Everything is dandy. But is it really? If not, then those who believe it is not should say so. Was this chunk symptomatic of a larger problem in a 56-year-old bridge? If it is true, to say so would not be sensationalism or scare-mongering. It would be much in the public interest, and it might help build public support for your overall cause.

In short, when there are tangible symptoms of infrastructure deterioration you should be ready to say as much. If necessary, call a press conference at the actual scene of the incident; when you plan your press conference think in terms of television's hunger for "visuals." But don't waste time. Try to do it on the same day of the incident or, at the latest, the next day. Two days after an overpass collapses it is a stale issue. Get yourselves organized in advance so you can spring into action promptly.

The third tip is to make a deliberate effort to make infrastructure as painless as possible for the public. If there is a public perception that those in charge of infrastructure repairs are insensitive to the convenience of the public, that perception may not help you in your long-term objective of putting the public on your side.

What do I mean by that?

You all know what it feels like to be stuck in traffic while there are road repairs.

Sometimes they are inevitable. No one could blame the road crews when traffic was delayed for 90 minutes on the Jacques Cartier Bridge that day when the unexpected happened. But usually these repairs are fully expected and are planned weeks, if not months, in advance.

I have editorialized several times about the way these repairs have caused enormous frustrations to the public. Often, extra lanes are blocked unnecessarily. No signs are posted in advance on highways warning motorists that the next exit is closed, so that motorists may have to use the next rather than the preceding exit and in some case have to backtrack, travelling 5 or 15 extra miles.

When I call around to find out the cause, the transport people blame the police for not alerting the public and the police blame the road crews and the road crews blame the planners and on it goes. No one ever accepts responsibility.

Administratively, it may not always be clear to outsiders whose responsibility it is. What is clear, though, is that you, as engineers and officials wanting to advance the cause of infrastructure repair, should make it your responsibility to see that these kinds of snafus are avoided.

According to the "book", it may be someone else's job, but you should make it your business to make sure that someone does that job well.

For example, last fall there were hugh tie-ups one day on the Trans-Canada Highway on the West Island. The provincial transport department had failed to erect signs alerting drivers to the fact that the next exit was closed. The ministry explained that it had not been negligent; quite the contrary, it said, it had followed its own regulations to the letter. Its regulations said clearly that if roadwork is going to take less than 24 hours, as was the case here, no advance signs need be erected. It was actual policy to ignore the public in such cases as these.

What I am saying is that people such as yourselves who are in the field have a responsibility to make sure that more than lip service is given to consideration of the public. Even if you are not a government official who makes policy, you should bring pressure to bear on those who do, to make sure those changes are made.

Some cities have special inter-departmental committees to coordinate the tearing up of urban streets to repair sewers or electricity cables. Often these committees do not live up to their billing. No sooner is St. Catherine Street in Montreal resurfaced after Hydro has torn it up, but the gas people descent to repeat the process and then the sewer people, finally, after three jackhammer invasions in 2 years, the city decides to install some wide sidewalks and fancy paving so it happens yet again.

In short, think in terms of public relations when you plan this kind of work. Public relations doesn't mean a fancy billboard saying "Your Highway Dollars at Work - We Regret the Inconvenience." Real PR means knocking heads to make sure everything that can be done actually is being done to minimize public inconvenience.

In some cases, this kind of initiative can go as far as appearing on hot-line shows. You can use that forum to tell the public what's being done, and why.

In other words, by making repairs less painful, you can serve your long-term goal of making the public less hostile to yet more ambitious repairs in the future.

In conclusion, don't get discouraged in advance about not getting media coverage because your cause is not glamorous or sexy. Most journalists can understand the importance of this issue, if you adopt an enterprising approach and show them, with documentation, why this is of genuine public interest. Finally, by minimizing the hassle element, you can make infrastructure rehabilitation a far less bitter pill to swallow.

INFRASTRUCTURE MANAGEMENT: A GEOGRAPHIC INFORMATION SYSTEM APPLICATION

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ABSTRACT

The infrastructure supporting Canadian cities requires immediate attention from both engineers and managers.

Engineering systems that enable such infrastructure to function and the technologies that will allow their rehabilitation can benefit from the computerization of municipal services and, specifically, engineering services.

The paper also focuses on the components of infrastructure management systems, the role of data collection and evaluation in support of the decision-maker. The benefits of computerized infrastructure management systems for city managers and public works directors also will be presented.

RÉSUMÉ

L'infrastructure sur laquelle reposent les villes canadiennes est à l'heure actuelle dans un état qui exige l'attention immédiate des ingénieurs et directeurs municipaux. Une bonne partie du débat relatif au renouvellement nécessaire a, jusqu'ici, porté sur le financement et l'amélioration des systèmes techniques. Le présent exposé porte,lui,sur la nécessité de meilleurs renseignements. Plus précisément, on y discute du rôle des nouvelles techniques, telles la conception assistée par ordinateur (CAO), les renvois géographiques, les cartes numérisées et l'inventaire informatisé de l'infrastructure, qui peuvent faciliter la réfection de l'infrastructure urbaine.

Le rôle de la collecte et de l'évaluation des données face à l'informatisation des services municipaux, plus particulièrement des services d'ingénierie, et les

avantages d'une telle informatisation pour les directeurs et décisionnaires sont mis en valeur.

INTRODUCTION

All infrastructure systems have to be regularly maintained, repaired, and overhauled.

This is the responsibility vested in city hall by the voters and it is as important as collecting taxes, planning new parks, and other city activities. In fact, Canadian cities spend at least one-quarter of their annual budgets on public works. City managers are attempting to find ways to resolve the problem of deteriorating infrastructure, and are constantly looking for rehabilitation alternatives to decrease costs.

City managers, public works directors, and engineers are working together to plan rehabilitation programs. They have to come up with the technical solutions and then translate them into capital investment programs or maintenance and repair schedules. The bottom line is that they must compete with all the other city services to obtain funds. These people require information so that they can map out a complete rehabilitation strategy for maintenance, repair and replacement. Only a well-structured information system with the capacity to handle large volumes of data on urban infrastructure, and to process it efficiently can help public works departments create adequate infrastructure rehabilitation programs. Thus, a key to solving urban infrastructure problems is information management.

MUNICIPAL INFORMATION MANAGEMENT

Municipalities manage a great deal of information. This information covers all aspects of municipal services: their costs, revenues, population served, territories covered, parcels and cadastres, and infrastructure.

Municipalities must cope with an ever-increasing volume of information as a result of the complexities of municipal management, which must comply with the regulations of numerous agencies, boards, commissions, and both the federal and provincial levels of government.

Some municipalities have mechanized their work orders, others their material inventories, and still others their plans and maps. Thus, there may be a water or fire-hydrant inventory, but not a street or a related water distribution network inventory. When a need occurs, an inventory or set of records is created. In any municipality a multitude of records containing similar, if not identical, information can be found in different formats. If a new need occurs and the existing record systems cannot meet it, another record is created. It seems almost impossible to gather all the pertinent information concerning the location of infrastructure in any specific geographical sector. In addition, much of the information on infrastructure is never written down. Most written information is in a manual, making it more difficult to sort and update information when required. Updating usually is not undertaken as often as it should be. As a result, many records are out of date and do not reflect the real location and status of the municipality's infrastructure.

Another problem that public works managers have to face is the relationship between many of the information records and the actual facilities or infrastructure. The records currently in place in municipalities are arranged in a number of different ways: for example, by address, street intersection, evaluation unit, or street block. For public works, different referencing methods often are used for different projects, making it practically impossible to link them together. Infrastructure work plans are as different as the number of services and engineering firms that produce them, and projects related to infrastructure management are often impeded because of poorly organized information.

A growing number of municipalities currently are being made aware of this situation, and many are beginning to consider reorganizing of their infrastructure information on a standard reference basis.

INFRASTRUCTURE MANAGEMENT SYSTEM

An infrastructure management system is basically a well-organized grouping of four fundamental components: information, equipment, procedures, and users. The function of such a system is to gather information, store it, process it, and make it available to the user. The system should have a common geographic reference base, so that public works managers and engineers can reference their work according to geography. It is difficult to imagine explaining the location of an underground water or street network without using any maps or drawings. Studies have indicated that as much as 90% of municipal information has some form of reference to geography. However, one of the key problems faced by an infrastructure management system is the form of organization used. The system must be multi-functional so that it can be adapted to the evolving needs of the different services that deal with infrastructure management.

Drawing the infrastructure systems on some form of common geographic reference is not enough. A map-based system, with no facility inventory to provide all the historical information concerning the infrastructure, is of limited use to the public works manager when he has to plan a 5-year infrastructure renewal program. The public works manager must know the installation date, the material, the maintenance and repair record, the uses of the facility, and other pertinent data. The manager has to be able to assimilate all this information, analyze it, and arrive at possible alternative solutions and corresponding costs. It takes a lot of time just to find the right information and undertake all the engineering and cost analyses required.

Recently, however, sophisticated tools have become available, specifically in the field of computer graphics and database management, to assist in the management of municipal infrastructures.

DIGITAL MAPPING

These tools are based on the widely-used computer-assisted design (CAD) technology. Map makers and engineers are using this technology to help them produce maps, and design and manage the structures they build on the area represented on those maps. Administrators, managers, and engineers increasingly are using maps as a source of information for decision-making. Having a computerized map is equivalent to having a word processor instead of a manual typewriter in an office. "Digital mapping" derives its name from the computer representation of a geographic map and the information represented on the map. Digital mapping has the following advantages over manual mapping:

- corrections are easily made;
- maps can be divided into layers according to the type of information (streets, house, property, water and sewer networks, cadastre);
- these layers can be combined or grouped for analysis;
- symbols can be altered to suit the needs of the user;
- maps can be varied in scale to suit the needs of the different services.

Municipalities using digital mapping as a common reference base can link these digital maps to their other records and represent their infrastructure systems on them. These facilities, when represented on digital maps, become an inherent part of the computer database. Systems that use digital mapping as a reference base for all the information are referred to geographic information systems (GIS).

GEOGRAPHIC INFORMATION SYSTEMS

A geographic information system in a municipal environment is created from the use of several technologies, such as digital mapping, data processing, engineering and management systems, to manage geographical information.

Essentially a geographic information system is equivalent to a management information system, except that a GIS integrates both graphic and non-graphic information related to geographic maps, land reference plans, and street and water main plans used for the management of municipal facilities. In addition, GIS can be interfaced with specialized management software to assist in the management of such activities as public works coordination, appraisal, network simulation, forecasting, measuring impact, design and analysis. A geographic information system must incorporate the following:

- a database,
- a digital map,
- data processing ability,
- communication ability, and
- decision-making assistance.

The system has to be able to store and process a vast amount of data and provide the pertinent information to the user. The system has to be able to differentiate between graphical and non-graphical data:

Graphical Data

- property lines
- stormwater networks
- sewer networks
- public right of ways
- land parcels
- cadastre
- building locations
- sidewalks and streets
- lakes and rivers

Non-Graphical Data

- street names
- civic addressess
- zoning
- sewer diameters
- manholes sizes
- types of permits
- assessment
- soil utilization

The graphical and non-graphical data are cross-linked by common geographic references. This cross-linkage greatly increases productivity in handling the vast amount of data in a municipal environment. For example, a public works engineer can ask the system to identify and locate all cast-iron water pipes installed before a specific date.

The advantage of such a system is the reduction in time required to search, gather, and process data. Municipal decisions thus can be made more quickly, and projects completed in less time.

In addition, with such a system, the right information can be accessed at the right time for such municipal activities as preparing the assessment roll, fire prevention, optimizing police patrols, planning of ambulance and other emergency dispatch services. The system also allows for more effective coordination between municipalities and public utilities.

The introduction of such a system into a municipalities does not require any radical changes in its existing operational procedures. In fact, a geographic information system should be adopted progressively on the basis of existing procedures and tools. It is more a matter of organizing information than drastically or radically changing operating procedures for a municipality.

INFRASTRUCTURE MANAGEMENT APPLICATION

To develop an infrastructure management application in a geographic information system requires that the infrastructure facilities inventory be input into the system. This task requires complete inventories of streets, wastewater mains, watermains, lighting networks, signs, sidewalks, poles, and other related infrastructures. All contract files and historical records also have to be input. These data are very important for infrastructure planning, budgeting, and maintenance management.

With such information at his disposal, the public works managers or engineers can readily plan several strategies for infrastructure renewal. They can also prioritize the areas of greatest need.

The infrastructure management application covers all activities related to the public works management:

- planning and design of infrastructure;
- preparation of engineering plans and estimate issue;
- operational management of municipal services including water, sewer, lighting, street cleaning, and traffic control;
- maintenance of urban infrastructures including planning of preventive maintenance, maintenance of street paving, bridge structures, and overhaul of underground networks for water and sewer;

- project management and control including project management for infrastructure construction, establishment of special overhaul programs, and project coordination.

To prepare an infrastructure overhaul program, a vast amount of data concerning existing infrastructure must be processed. The geographic information system, through the infrastructure management application, can provide the necessary data and process it into information for rapid decision-making, or it can sort out various alternatives to help implement the most efficient renewal strategy.

PLANNING FOR THE INFRASTRUCTURE MANAGEMENT APPLICATION

The planning of such an application requires that the municipality first establish some form of geographic reference through a geographic information system. A facility inventory has to be created and the required management systems established. A considerable amount of technical knowledge, both of the functions of infrastructure management and of computer technologies, is required to propose functional infrastructure management applications in a geographic information system.

The development of such a system, and its integration into the existing operational procedures of a municipality, require a great amount of time and effort. In the long-term, however, the benefits of such management systems far outweigh their initial cost. The introduction of these new technologies to assist public work managers has become increasingly prevalent. Many municipalities in both Ontario and Quebec have begun projects in such areas. Some municipalities in western Canada have quite advanced geographic information systems with such applications as infrastructure management.

CONCLUSION

Any renewal program requires that the public works manager find out the location and condition of municipal infrastructure. The manager also has to organize his information so that it is readily accessible for decision-making.

Geographic information systems provide the necessary structure to develop municipal management systems and to automate specific functions, such as infrastructure management. Geographic information systems with an infrastructure management application should be a prerequisite for any municipal infrastructure renewal program given their potential to optimize costs and generate the most suitable renewal strategies.

MUNICIPAL SERVICES: REPAIR OR REPLACE?

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ABSTRACT

The question of whether a particular municipal facility, such as a road, sidewalk, sewer, or watermain, should be repaired or replaced is reviewed under three headings:

Technical Factors: utilization of computer technology for individual and integrated services; impact on capacity considerations;

Funding Availability: existing debt limitations that preclude replacement; priorizing of available funds; availability of funding from other levels of government;

Community Desire: the decision to repair or replace is governed to some extent by the level of service desired by the community.

RÉSUMÉ

L'auteur examine les facteurs influant sur la décision de réparer une installation municipale particulière, tel une route, un trottoir, un puisard, une canalisation d'eau, etc., en les répartissant en trois catégories:

- les considérations techniques: emploi de techniques informatiques pour des services individuels et intégrés; importance des considérations de capacité;

- la disponibilité de fonds: impossibilité de remplacer l'installation en raison des restrictions imposées par la dette du moment; établissement d'un ordre de priorités pour l'utilisation des fonds disponibles; accessibilité de fonds provenant d'autres ordres de gouvernement;

- le désir de la collectivité: la décision de réparer ou de renouveler une installation est, dans une certaine mesure, dictée par le niveau de service désiré par la collectivité.

INTRODUCTION

The question whether to replace or repair a particular municipal service, such as a road, bridge, sewer, watermain, etc., in a given year is an important issue in any municipality. It is also difficult to answer precisely but it can be reviewed under the following three headings:

- technical factors
- funding availability
- community desire.

TECHNICAL FACTORS

Using Modelling Programs

Computer-based pavement management packages, which provide information as to whether it is preferable to repair or to replace a road structure, have been available for several years. Other more comprehensive computer systems are now becoming available. For instance, the City of St. Paul, Minnesota, "is developing a comprehensive Infrastructure Management System that includes detailed facility inventories and condition assessments, maintenance management systems, and computer-aided mapping/graphics capabilities. The system is being put to two major uses, capital improvement planning and maintenance management. It provides better information for decisions about repair, renovation or replacement. Integrating inventory data into computerized maintenance management systems streamlines scheduling and provides immediate updating of inventory schedules" (1).

Regarding the whole concept of infrastructure management systems (IMS) in general, the comment has been made that, "In managing public infrastructure sub-systems, it has been an all too common practice to make decisions based upon annual budgets without regard to longer-range trends in system conditons and projected resources. This situation has been exacerbated by the growing fiscal gap between public works funding and the escalating cost demands of a generally deteriorating infrastructure, whereby the agency is trapped into responding to one crisis situation after another. Consequently, projects often are designed and implemented incrementally, based on the current, or at best, next budget cycle as funding dictates, rather than as elements in a planned sequence of system maintenance and improvement. Implementation of an IMS can help an agency overcome this myopia in decision-making by both encouraging and supporting more rational planning." However, it has also been pointed out, as a cautionary note, that, "The IMS can be an excellent tool to assist in decision-making, but it is not a substitute for engineering judgment, nor does it account for a variety of economic, social and political intangibles. The IMS is a model that approximates human judgment as to system conditions and needs, cost effectiveness of treatment strategies, system priorities, and expenditure allocations. It must be validated/adjusted continuously to reflect this real world view."(2)

Comprehensive Consideration of Reconstruction

If a decision has been made to reconstruct a pavement, it will often be preferable to also replace the underground systems such as sewers and watermains, as well, even if their lifetime has not fully expired. This course of action will probably be preferable to excavating the new pavement in the future to replace the underground systems when their lifetime has expired.

Capacity Considerations

In many cases capacity considerations will govern the repair-or-replace decision as follows:

a) Obviously pavements may require widening to accommodate traffic flows before the time at which reconstruction to the same width would have been required. In such instances, a further decision will be required as to whether new widening strips should be placed alongside the old pavement or, alternatively, if an entirely new pavement for the full width should be provided. In such cases, the pavement management packages described previously will be of assistance.

b) In a similar manner, a new sewer or watermain may be required to provide capacity to meet present-day service needs, even if the lifetime of the existing service has not expired. This will be especially the case for storm sewers, where present-day design criteria require larger sizes than in the past.

FUNDING AVAILABILITY

The following factors surrounding funding availability affect the repair-or-replace decision:

Funding Priorities

A basic task of any municipal council is to priortize and allot the scarce resources available from property taxes, the only basic source of revenue that municipalities have. In any given municipality it may, for instance, be necessary to allot a large amount of these resources to the construction of a new or expanded pollution control plant, or the construction of local sanitary sewer networks to eliminate pollution caused by septic tanks and tile beds. These priorities will by themselves, render funds unavailable for the reconstruction of other services, such as roads and sewers, thus favouring a repair decision. This decision will probably mean that a higher and, thus, more expensive level of maintenance will have to be provided to prevent progressive deterioration of the service from occurring before complete reconstruction can eventually be funded. For instance, if total reconstruction of a roadway is not financially possible, resurfacing may be essential to prevent moisture infiltration from completely destroying the pavement structure.

Limit of Debt Burden

In many municipalities, repair work is carried out from current funds, whereas replacement of services is frequently carried out using debentured or borrowed funds. In regard to the borrowed funds, a municipality may already have reached its allowable limit of debt burden and, therefore, only repair will be possible with current funds and not replacement with debenture funds.

Financial Assistance From Senior Government

The repair-or-replace decision obviously will depend to some degree on the level of financial participation in the project by other levels of government. For instance, in Ontario, connecting link pavement reconstruction or widening projects, which receive 75% funding from the province, normally proceed as soon as provincial approval is received. Other road projects that attract only a 50% subsidy, may not proceed because of lack of local funds, even though the provincial share is available. (Since provincial road subsidies are funded by revenue, i.e. user fees, from the driving public, this means that user fees collected in one municipality may be in effect transferred to another municipality which has matching funds available).

The following points may also be noted with regard to funding from other levels of government:

a) Provincial road subsidies (at least in Ontario) have neither kept pace with inflation nor, indeed, with the revenue increases to the province from user fees. The only possible outcome of this trend is, of course, the continued deterioration of municipal pavement structures because municipalities have no additional sources of revenue available to them to make up the shortfall.

b) The past decade or so has seen a gradual withdrawal of federal funding assistance for the construction of municipal services, particularly with respect to pollution control plants and neighbourhood improvement programs, both of which, were previously funded in part by the federal government.

COMMUNITY DESIRE

The decision to repair or replace will also be governed to some extent by the level of service desired by the general community. All individuals, consciously or not, select their own level of personal service: they decide either to continually own a particular automobile no longer than, say, one year, or continually to repair the automobile for several years and trade off lower capital cost outlay against the prestige and attractiveness of a late-model automobile. Similarly the community generally makes its collective will known to the elected body if the level of service for road surfaces, sidewalk cracks, low water pressure, backed-up sewers, etc., is below what the community collectively desires, and if the community is prepared to pay the higher property taxes required to maintain a higher level of service. All this may sound neither precise nor capable of quantification. Indeed it is not, but nevertheless, the overall community's willingness to pay for a particular level of service will influence decisions as to whether a municipal facility should be repaired or replaced. Community desires in this regard also will be affected by the matter of cost minimization to the public. For instance, road surfaces obviously can reach such a state of disrepair that it is more economical, from a total cost viewpoint, for the community to bear the cost of complete reconstruction rather than the mounting cost of automobile repairs necessitated by the poor pavement surface.

SUMMARY

The decision as to whether to repair or replace municipal services will be based initially on technical considerations, but also will be influenced by considerations of funding availability and community desire. The latter two factors will be of primary concern to the elected council since they have the responsibility of balancing the community desire for adequate services against the willingness of the property taxpayer to accept a certain level of taxation. The first factor, the technical consideration, is basically the responsibility of the municipal civil servant, who will find it necessary to utilize ever more sophisticated methods of infrastructure analysis and management in formulating recommendations to the elected body. The resultant combination of the political expertise of the elected body and the technical and/or managerial expertise of the civil servant will tend to ensure that the optimum repair-

or-replace decision is made in each instance. In the past, the emphasis has been on building new infrastructure and not enough attention has been paid to managing the maintenance of the existing infrastructure. Now all that is changing, primarily as a result of financial pressures, and the science and art of total infrastructure management is developing rapidly and will undoubtedly be a major force on the local government scene henceforth.

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THE INFRASTRUCTURE RENEWAL PROCESS: A CONTRACTOR'S PERSPECTIVE

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ABSTRACT

The challenge to today's contractor is to educate himself in new methods and materials. This means the engineering community must be willing to depart from traditional methods and adopt new technologies.

Drawing on the experience of 30 years, this paper examines such issues as hidden costs, government spending practices, the need for a continuing inventory of infrastructure condition, and requirements and greater public awareness.

The efforts of TRIP/Canada, of which the author has been National Director, of the Federation of Canadian Municipalities' Task Force on Infrastructure and of the Roads and Transportation Association of Canada to promote the advantages of urban infrastructure investment are examined.

RÉSUMÉ

L'entrepreneur d'aujourd'hui est constamment mis au défi de se former à l'emploi de méthodes et de matériaux nouveaux. La collectivité technique doit être prête à laisser de côté les méthodes traditionnelles pour adopter les techniques nouvelles.

S'appuyant sur trente années d'expérience, l'auteur examine des questions comme les coûts cachés, les pratiques des gouvernements au plan des dépenses, la nécessité de se mettre sans cesse à jour sur l'état de l'infrastructure, les besoins qui en découlent et ce à quoi s'attend le grand public.

L'exposé porte sur les efforts de TRIP/Canada, dont l'auteur a été le directeur national, du Groupe d'étude sur l'infrastructure Imunicipale de la Fédération canadienne des municipalités et de l'Association des routes et transports du Canada en vue de promouvoir les avantages de placements dans l'infrastructure urbaine.

I started in construction business as a young man, with keen eyesight, in good physical condition, and a life-span of 25 years, if I kept in reasonably good shape. Today my eyes are not what they were, and I suffer from middle-age spread. That results from overwork of the system, as well as other priorities and interests that interfere with timely and adequate checks and balances to keep the system operating at peak efficiency.

That is what has happened to another system in the same period of time, our infrastructure.

In the early 1950s we began our urban spread: subdivisions, or so-called "bedroom communities," which demanded new services to move our people to and from work. The response was massive, and, in some areas across Canada, still is.

Twenty years later we should have been examining the condition of the plant, the infrastructure, but instead we ran into a recession, complicated by the costs of social programs which had been put in place, and it became necessary to patch rather than repair and to coax more out of a system that was never intended to carry the load of today's needs either in transportation or in other services.

Public awareness of these issues is the objective of The Road Information Program (TRIP/CANADA). Our mandate is to inform the public on the physical condition of our roads, bridges, sewers, and water treatment and delivery facilities. The public view that a road once built, or a service once installed, will last forever, has to be changed to provide support for the politician. Because pot-hole patching, a politician's answer to our decaying infrastructure, has to stop.

A tremendous cost is involved in bringing our systems to the good condition that Canadians should be able to expect.

But there is a much larger cost, an almost unaffordable one, in delaying the inevitable by continuing to ignore the problem. Some cities in the United States have almost reached that stage, and we cannot let it happen here. Simple replacement is, unfortunately, not a total answer, because many of our existing services are under-designed, and therefore inadequate to meet today's needs. For example, our road system was not designed for today's traffic counts and loads.

With infrastructure renewal both the engineer and the contractor face many challenges:

- new technologies in lining existing piping rather than ripping it out and replacing it, and
- newer materials, for some of which the life-span is still unknown.

From the consultants and city engineers, a better understanding of the contractor's problems in renewal work and the method of tendering for it is needed.

- if penalty clauses are to be inserted in contracts, then just as surely, bonuses for early completion have to be the other side of the coin;

- items such as curb replacement, sodding repairs and granular backfilling, when replacing a system, have to be payments, not buried in the tender call as contractor's responsibilities;
- we don't know any better than the consultant what the ground condition will be until it's opened up, despite the odd soil report from consultants; and
- we need better supervision in our work, a closer examination of our costs to survive: a bare-bones approach to a bare bones industry.

We are paper-bound with regulations, burdened by the noise of our machines and the hours we can work, and crippled by the costs of benefits to our employees that politicians have seen fit to apply.

The only bright side we see is the interest being generated in our sector of construction, and the possibility, not yet probability, of an expanded marketplace to begin putting our companies back on their feet.

Across Canada our sector of industry operates on a 50% unemployment factor and that is a cost to all of us that we can ill afford. For every job created in our industry there is a multiplier of at least 2.5. Our work has an effect on the employment of sales people, the engineering community, suppliers, draftsmen, insurance men, and equipment dealers, to mention only a few. Today we pay, on average, $7.00 an hour for our productive labour force to sit at home on U.I.C., or welfare to others who do not qualify for U.I.C.; we have thus created a generation of unemployed. The costs are in the billions of dollars.

The rationale of economic benefit to the nation from infrastructure reinvestment, was the topic of an OECD conference on infrastructure I attended as the Canadian delegate in December, 1985, in Paris, France. OECD has a membership of about 20 countries; its advice on economic matters is respected and followed. It turns out that the problem of underfunding, and the resultant decay of the system, is not unique to Canada and the United States. It exists across what we call the free world. The 3-day conference of management personnel and trade union representatives resulted in a paper called "Infrastructure Investments and Their Contributions to Employment and Economic Growth".

This paper was released for general distribution to all member governments in March, 1986, and recommended that infrastructure reinvestment be used as a major tool in economic recovery. So far there has been no position from the Government of Canada on either its findings or its recommendations.

The Federation of Canadian Municipalities and The Roads and Transportation Association of Canada have succeeded in raising the public awareness of the need for infrastructure renewal. Our reports (23 to date across Canada) or the Federation's views, in its report of June, 1985, are the subject of newspaper articles across Canada almost daily.

Our role was to create public awareness, and we believe we are succeeding.

But, political reaction and then positive action to address the nation's needs are stumbling blocks yet to be overcome. We have yet to find a federal politician to take up the cause despite its inherent economic benefits. Ottawa's reluctance to participate can only be reversed with public education and public pressure. That's why we in TRIP/CANADA have elected to carry on with our campaign for another 3 years. We are in the process of releasing a major water and sewer report here in Ontario. It refers not only to the tremendous public investment of about $20 billion at stake in this province in water distribution systems alone, but also to the fact that maintenance and upkeep of that system is currently underfunded by 75% of what is required to assure Ontario residents served by the municipal water systems the continuation of a reliable, adequate supply of water. That 75% is $175 million a year.

We've seen some progress in the last 3 years, the public is beginning to understand that we cannot take our systems for granted.

Given that the need is evident, then where will assistance come from?

The Canadian Construction Association is beginning to lobby for the imposition of a $0.01 per litre fuel tax to generate funds to improve our nation's principal highways. That lobby, if successful, would generate $500 million a year, which, if added to present levels of funding, would, over a 5-year period, bring about the repair of our major transportation links across Canada. TRIP/Canada supports that lobby.

We see the same criteria being needed to fund urban infrastructure - dedicated funding raised through frontage charges for programs. New money, dedicated funding, is required.

The construction community across Canada is united in support of our TRIP/program, just as we who are directly involved in its public awareness campaign are supportive of the Federation in bringing about infrastructure renewal in Canada.

APPROPRIATE MANAGEMENT TECHNIQUES: INFRASTRUCTURE, PEOPLE, AND MONEY

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ABSTRACT

As our society moves rapidly into an increasingly turbulent period, institutions will have to adopt new approaches to maintain productivity. Open, participative management techniques are required to motivate staff towards self-management systems.

Declining revenues for public works departments continue to exacerbate infrastructure rehabilitation problems. New and appropriate revenue generating techniques are required. One approach is to try to increase infrastructure's share of the municipal budget through program budgeting techniques which emphasize needs and the consequences of inaction.

RÉSUMÉ

Le réaménagement de l'infrastructure urbaine suppose deux éléments essentiels: des gens et de l'argent.

Les directeurs des travaux publics doivent motiver leurs effectifs et favoriser leur engagement. Ils ont pour ce faire divers instruments de gestion, notamment des techniques de leadership de circonstance et des moyens efficaces de déléguer les tâches. L'amélioration des communications avec la main-d'oeuvre et avec les représentants politiques est une condition essentielle de l'obtention des résultats recherchés.

Les directeurs ont également divers instruments financiers, y compris différentes formes de budgétisation des programmes, qui leur permettent de proposer aux décisionnaires politiques une gamme assez variée de programmes et d'indices de

mesure du rendement pour que ceux-ci fixent les affectations budgétaires en fonction des besoins véritables et de priorités soigneusement réfléchies.

INTRODUCTION - INFRASTRUCTURE NEEDS

Today's new reality of "rising needs and declining resources" means that public works administrators will have to adjust their operations to enhance their efficiency. Declining resources imply increased levels of conflict among civic officials as each struggles to maintain his department's legitimate claims for an increased share of shrinking revenues. The municipal engineers' approach of "making do" may have caused their operations to bear much of the brunt of municipal budget cuts. Despite their ability to do the best possible with limited resources, minimum levels in public works operations may have been reached. Public works administrators must become increasingly visible, their voices, shouting the needs of infrastructure rehabilitation, must be heard above the tumult of those of other departments.

One of the primary problems facing public works administrators is that the maintenance and rehabilitation of existing public works facilities has rarely been seen as a visible, "vote-getting" political activity. "Glamorous" projects, such as constructing new buildings and creating parks, tend to outshine routine infrastructure activities. Often these new facilities incur increased operating and maintenance costs (possibly unforseen in the planning stages) which further exacerbates conflicts in allocating scarce maintenance and rehabilitation funds.

Fiscal retrenchment and cut-backs come at a time when civic administrators are becoming increasingly aware of the aging and deterioration problems of their stock of municipal infrastructure. Various studies have demonstrates the growing need to address infrastructure rehabilitation (4,18). A recent report by the Federation of Canadian Municipalities (FCM) demonstrated that if the identified urban infrastructure needs in Canada were to be addressed over a 10-year period, public works budgets would require an annual increase of 22% (6).

Many of our municipal engineers were trained during our earlier era of economic expansion, a period when emphasis was placed on continued growth of the municipality's physical plant to service spreading suburban areas. Today's growing infrastructure rehabilitation needs demand a shift away from development and construction towards an emphasis on maintenance and rehabilitation.

Organizationally, new managerial approaches are required to motivate staff at all levels and instill in them a sense of dedication. Similarly, different techniques for raising revenue for infrastructure rehabilitation will have to be explored and instituted. A greater understanding of the municipal policy formulation process is required so that key pressure points can be identified. One such pressure point involves the annual municipal budget. Developing appropriate budget mechanisms may enable municipal engineers to articulate their departments' needs more clearly for a greater share of financial resources.

Rapid changes in our society are forcing organizations to adopt survival strategies. Many of these adaptive strategies, such as environmental scanning (maintaining a watching brief on external events), establishing clear goals and directions, and shifting to an organic organizational structure, have a role to play in local government organizations (9).

PEOPLE AND INFRASTRUCTURE

The rapid shift of our society away from heavy plant towards the information and service sector has meant a shift away from the view of capital as machinery and equipment to considering an organization's capital its stock of people. Increased productivity in today's computerized world comes not from better machines, but from more motivated staff. A manager's job is increasingly one of providing guidance and leadership rather than monitoring and controlling staff. How can a manager generate motivation, enthusiasm and productivity from staff? What new demands are being placed on public works managers in our rapidly changing society?

Motivating Staff

Public works departments traditionally have been organized in a bureaucratic hierarchy, one in which strict rules and operating procedures are established to force all employees rigidly to function in pre-ordained ways. Such inflexibility thwarts the innovative approaches necessary for coping with changing circumstances. Adhering to the rules often becomes the main goal of autocratically ruled departments and divisions. Since there is no reward for successful risk (making discretionary decisions to deal with unique situations), departmental staff soon hide behind their rules. Such focusing on the rules, rather than on what they were meant to achieve, frustrates council, citizens (the organization's clients) and other civic departments.

Another inherent problem within rigid bureaucracies is their poor internal communications system. Typically, communication, in the form of orders and directives are top-down with little feedback. This creates serious problems for public works administators who need to know how their services are satisfying their clients' (the citizens) needs. Often the labour crews on the street are in better touch with the problems facing average citizens than is the city engineer.

The bureaucratic model was the traditional means of harnessing the "muscle power" of the industrial era. It was an appropriate model for a period in which

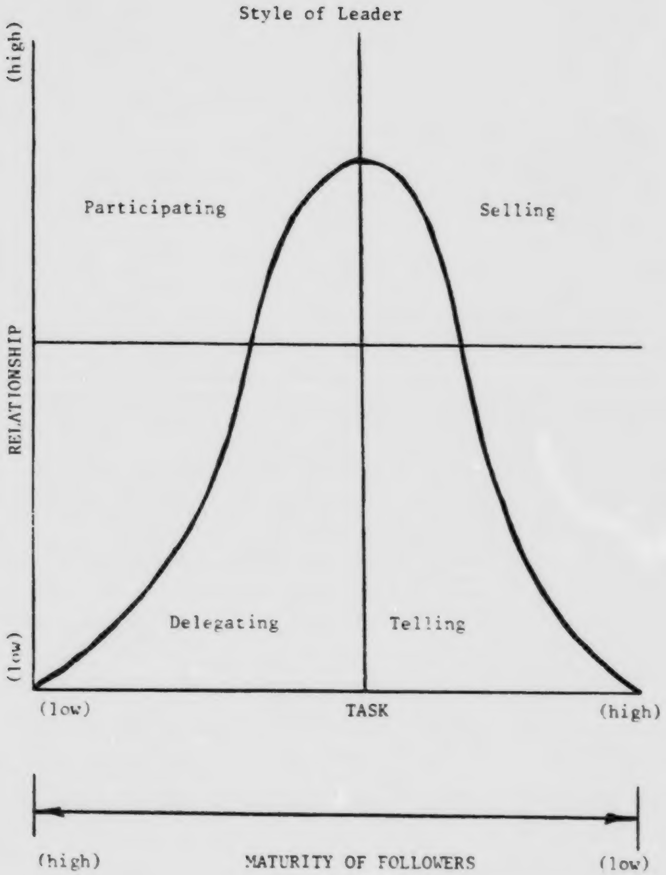
Style of Leader
(high)
RELATIONSHIP
(low)
Participating
Selling
Delegating
Telling
(low)
TASK
(high)
(high)
MATURITY OF FOLLOWERS
(low)

Figure 1. Situational Leadership Model

emphasis was placed on standardization, specialization, synchronization, concentration, maximization, and centralization. These features resulted in

> ... a classical industrial bureaucracy: a giant hierarchical, permanent, top-down, mechanistic organization, well designed for making repetitive products or repetitive decisions in a comparably stable industrial environment (20).

Bureaucracies functioned well in stable environments. However, the rigidity and adherence to rules, which made bureaucracies efficient and functional in the stable industrial era, hamper these organizations in adjusting to today's new realities. Rigidity implies resistance to change. Restricted internal communications within bureaucracies often prevents the organization from perceiving changes in the environment and their need to incrementally adjust their activities to meet new demands. In most cases, bureaucracies do not respond to changing conditions until the situation reaches crisis proportions.

Situational Leadership

The style adopted by a leader reflects the maturity of his followers. In Hersey and Blanchard's, "Situational Leadership" model (Figure 1), the degree of task and relationship vary with the maturity of staff. One approach to motivating workers is to create quality circles, a means by which workers meet together to identify, analyze and solve their own problems with the active support of management. Quality circles ensure workers become involved in the organizational decision-making process.

Quality circles and worker involvement within the organization pays considerable dividends in terms of enhanced productivity. Staff members at all levels gain a better understanding of and bring greater commitment to departmental goals, working together on common problems increases the cohesion of the labour force, and participative approaches improve vertical communication, putting senior officials in better touch with the changing needs of the community. These participative approaches, however, will not work unless senior level management is prepared to listen and give serious consideration to suggestions from their labour force. Establishing goals and effectively communicating them to all within the organization begins to modify individual behaviours, but it is really the consequences of these actions which maintain behaviours (positive reinforcement) (2).

Self-management among all employees is a goal readily achievable for most public works organizations. New managerial thrusts toward open, participative approaches will increase productivity and enable public works organizations to tackle difficult infrastructure rehabilitation problems more readily.

Organic Structure

Parallelling the development of self-management approaches is the need to restructure the organization to cope better with today's rapidly changing environment. Organizational studies have found that, depending upon the task and environmental circumstances, different organizational forms are required (3,13). As the operating environment of local governments becomes increasingly turbulent, a more organic approach is required to replace the bureaucratic model. Toffler has suggested that organic organizations in a turbulent environment:

> ...have flatter hierarchies. They are less top-heavy. They consist of small components linked together in temporary configurations. Each of these components [task forces] has its own relationship with the outside world ... organizational players need to be trained for instant adaptation, and they must feel comfortable in a wider repertoire of available organizational structures and roles (20).

Figure 2 provides a comparison of the characteristics of the bureaucratic and organic organizational models. These two approaches should be considered to be opposite ends of a spectrum of organizational variations. The appropriate approach for a given organization depends upon its specific circumstances.

The organic approach lends itself to the creation of interdisciplinary, task-oriented project teams in which leadership depends upon team consensus, rather than on authority definition, and communication is open and informal. Obviously the success of project teams depends upon the commitment and motivation of team members, there is a need for mature, responsible, self-managing employees. The example likely to be familar to public works administrators is the matrix management approach of many consulting engineering firms. This method of organizing a project team entails blending together a group of multidisciplinary individuals to tackle a problem. They then disband and reform for other tasks. As pointed out by Bennis, in our turbulent environment:

> Tasks will become more technical, complicated and unprogrammed. They will be too complicated for one person to comprehend to say nothing of control. Essentially, they call for the collaboration of specialists in a project- or team-form of organization (1).

		Mechanistic	Organic
1.	Tasks and Structural Positions.	Specialized and limited; Rigidly defined; Assigned by superiors; Routinized.	General and diverse; Continually reassessed; Defined through interaction; Non-routinized.
2.	Personnel	Selection on the basis of technical competence, qualifications; Obedience valued, follow rules.	Selection on the basis of social as well as techical competence; Responsible role playing valued.
3.	Individual Corporate Responsibility	Limited to assigned tasks; Prescribed by formal rules, regulations and job descriptions and hierarchical position.	Limited to assigned tasks stemming from commitment to mission, limited only by ability; Prescribed by formal rules related to organizational mission, shared throughout hierarchy.
4.	Decision-making and authority	Tops-down; Non-involvement in policy development; Restricted to implementation; Centralized.	Participatory; Involvement in policy development; Not restricted to implementation; Decentralized.
5.	Interactions	Vertical; Impersonal; Restricted information; Low feedback; Closed conflict; Formal.	Vertical, lateral & diagonal; Personal; Open information; Open conflict; Informal.
6.	Leader-Subordinate Relationships	One-to-one; Limited access to leader; More adherence to hierarchical levels; Telling - reporting superior - subordinate relationship.	Team leadership; Open access to leader; Leadership positions flexible, defined by consensus; Lateral consultation; Decision by consensus.

Figure 2. Comparison of Organic and Mechanistic Organizational Models (12:20)

Although many larger bureaucracies will be unable to change their bureaucratic systems radically, they may be able to adapt by structuring temporary task forces drawn from various parts of the organization to deal with specific problems. In this manner, their mechanistic systems will be able to deal with significant changes in their external environment by making timely adjustments.

Changing Organizations

Shifting to a more organic approach and participative management implies changes to the organization. Such changes do not come about easily, one must ensure that the rewards created by change outweigh the costs of the transition period. Prior to initiating an organizational change, three major issues must be conciously considered:

- the resistance the proposed change will meet;
- controlling the organization during the turbulence of transition; and,
- dealing with changes in the internal power structure.

The organization must be motivated to change. The initial step is to identify clearly those sections where there is dissatisfaction with the current situation. The greater the pain and dissatisfaction, the higher the motivation for change. To initiate change, a clear image of the organization's expected future state must be established, special transition management structures created (task forces), and, a participative system established. During the transition, top leader support must be maintained, desired behaviour rewarded, time for disengaging from the current state provided, and progress towards the expected future state monitored.

Management Development

Today's public works administrators require far more than the technical/ professional skills of their predecessors. They must be able to predict the effects of change in their environment accurately and quickly make appropriate adjustments in their organizations. They must be able to function equally well in organic or bureaucratic systems and be clearly aware of the need for differing approaches. They must act as facilitators, teachers, and counsellors. They must understand the policy process, how and when the key decisions are made which effect their operations, as well as their role in council-staff relations. And, finally, they must enhance their communication skills, both oral and written, to ensure their message of the pressing need for infrastructure rehabilitation is clearly presented and received.

The increasing technical complexity of our society is placing political decision-makers into a position of greater dependence on their administrative staff. Without due care and sensitivity in developing council-staff relations, increased and unnecessary friction will emerge, particularly when faced with conflict situations such as the allocation of scarce financial resources (8). To avoid these conflicts and to maintain their effectiveness in providing municipal services, public works administrators must recognize and respect their role as policy advisors. Similarly, elected councillors must abide by their role as policy-makers and refrain from delving into administrative matters. Achieving effective municipal operations implies a partnership between politicians and administrators. Both must respect one another's political astuteness and technical competence. Establishing infrastructure rehabilitation as a priority requires both technical and political inputs (10).

Management Training

Enhancing the ability of public works administrators to function effectively, both as participative managers and as policy advisors, requires training and development. One of the characteristics of bureacracies is their "imprinting" function, through which the current values of managers were shaped during their earlier, formative years in the junior echelons of the organization (15). These attitudes must be changed to cope with today's needs. Value modification stems from education. A wide range of options are available to public works organizations from continuing- education opportunities in universities and technical colleges to more intensive, short-term, in-house training programs.

Another, more technical concern involves the abilities of municipal engineers to deal with the maintenance and rehabilitation needs of public works infrastructure. For far too long, civil engineering departments in our universities have focused on training engineers to construct new capital facilities rather than to mainten and rehabilitate existing plant.

Much of the current knowledge of infrastructure rehabilitation techniques has resulted from empirical work in the field rather than academic research. An appropriate medium is required to tap this knowledge and distribute it. One means of achieving this objective has been the continuing education seminars sponsored by the American Public Works Association. Although these seminars provide an effective forum for knowledge and technology transfer, their low frequency of offering in Canadian centres puts them out of reach of most public works administrators. Using these seminar formats as a model, perhaps the FCM, in conjunction with the Canadian Public Works Association, could develop regional forums for sharing information and advice on infrastructure rehabilitation issues.

MONEY AND INFRASTRUCTURE

Even with well-motivated and committed staff, little can be done to improve infrastructure rehabilitation if funds are not available. The issue of money can be dealt with at two levels: first, identifying revenue-generating methods to provide additional funds for infrastructure work; and second, allocating municipal revenues for infrastructure needs through the annual budgeting system.

Generating Revenue

During the past decade public works budgets in Canadian cities have been falling in real terms. As shown in a study by the American Public Works Association, the average annual decrease of Canadian municipal public works operating budgets (exclusive of capital construction) from 1977 to 1979 was -1.78%. In 1970, Canadian public works departments on average commanded 60.4% of their total municipal budgets. By 1979, this share had dropped to 41.9% (18). Similar reductions in public works capital investments were also apparent. This dramatic decline "reflects the growing habits of governments at all levels to cut back on construction, rehabilitation and maintenance in order to balance budgets, hold down the rate of tax growth, and finance a growing menu of social services" (4). Shifting budget priorities in local government has meant, in many cases, that maintenance items have been deferred in favour of more politically popular activities. Deferred maintenance may mean increased costs in the future as replacement rather than repair becomes necessary.

Financial restraint at all levels of government has shrunk the tax window available for local governments. Approaches other than property taxes have to be used to overcome current revenue shortfalls. Although some of the following revenue-generating methods may not be applicable in Canadian municipalities, they do raise some interesting perspectives.

The "user pay" system has been used to generate revenue for many municipal services. In particular, Canadian water treatment and distribution systems obtain about 84% of their required revenue directly from their users (6). Sewage collection and treatment systems are also funded by about 56% by users, generally indirectly through water rate charges. User charges for municipal roads and bridges are minimal. User fees can generate additional revenues through fees on toll bridges and roads, recreation fees and public transit charges. Other examples of user fees include the collection of gasoline taxes and license fees as a means of offsetting roadway system costs. Appropriate user fee rate structuring may encourage conservative and more efficient use of available facilities; comparative studies of water-metered and non-metered communites have shown that this often is so.

Impost fees, a form of connnection charge, may be levied against new subdivision lots as a means of providing revenue for infrastructure expansion to serve the new development. Many Ontario municipalities use impost fees or lot levies as a means of raising revenue.

Infrastructure renewal either through rehabilitation or replacement is often expensive and requires capital borrowing. A number of approaches have been generated in U.S. municipalities as a means of reducing capital requirements (6). These include:

- zero coupon bonds - municipal bonds in which interest payments are deferred to maturity;
- leasing schemes - lease purchase arrangements where by private sector investors provide capital infrastructure facilities and lease them to municipalities leading to their eventual ownership;
- privatization or contracting out to private sector firms to provide facilities and services; and
- interim privatization - a process through which private companies construct, rehabilitate, maintain and operate a city's sewers, streets or other infrastructure for a fee. Once the incurred debt is repaid, the facilities would revert to municipal ownership (4).

Although these techniques may augment current public works budgets, they must be handled with care. For example, water rate setting should be equitable (19). Indeed, the whole issue of generating revenues has equity implications.

Other internal revenue-generating approaches also may be applicable. Ensuring projects commence without unnecessary administrative delays will reduce costs which, in turn, yields revenues for other activities (18). Similarly, improving organizational efficiency to reduce waste, minimize inventories, and encourage recycling in an overall conservation effort also will release scarce funds for other more pressing infrastructure needs.

Municipal Budgets

Public works activities have continued to lose their share of the total budget as new priorities have emerged. Today's infrastructure needs likely will become the budget priorities of tomorrow.

Traditionally, municipal budgets have been set up as a line item or object accounting process. In line item budgets, the object of expenditure is identified along with a comparison of previous spending of that item. Line item budgets provide a strong degree of management control over the expenditure of resources. The main problems with this form of budgeting are that:

- first, the focus of attention is on resource inputs rather than the outputs they are meant to generate; and
- second, the lack of program identification makes it difficult for policy-makers to rationally cut-back on proposed expenditures.

In more recent years, budgeting approaches in many of Canada's major municipalities have shifted away from line item systems to more rational program budgeting. Program budgeting focuses on the outputs of resource expenditure rather than on the inputs, in other words, on the value obtained from the money spent. Program budgeting emphasizes planning, programming, and quantitative analysis. For each program provided by the public works department, the budget submission includes the program's goals and objectives, some measure of its effectiveness (quantitative performance measurements), and how it interacts with other municipal activities. Providing budget information in a program format enables elected officials to make discriminating choices among competing needs.

A program budgeting approach should enable public works administrators to establish the pressing needs of infrastructure rehabilitation more clearly. Through the use of appropriate performance measurement indicators, municipal engineers can demonstrate not only the improved efficiency of their operations, but also the need to rehabilitate the community's physical plant.

CONCLUSIONS

Resolving today's pressing infrastructure problems requires far more than innovative technical solutions. People, staff at all levels, must be motivated and encouraged to use new approaches and increase their productivity. Motivation arises not only from the financial compensation a job provides; but requires praise, support, and participative management approaches. Public works administrators will have to adjust to our changing society and adopt managerial styles appropriate to their followers' needs to increase overall productivity.

Along with people, the second major factor involved in infrastructure rehabilitation is appropriate funding. In recent years, public works departments have seen their relative share of the total municipal budget shrink as new and politically more attractive activities have attracted increased attention. Municipal engineers will have to develop various revenue-generating schemes to enable the present physical plant to be rehabilitated. "User pay" schemes in their many variations seem to have the most potential, although they must be used with care to avoid inequities in municipal service provision. Other methods of revenue generation, including enhancing the efficiency of current operations, also may provide opportunities to offset declining budgets.

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STRUCTURING THE INFRASTRUCTURE

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ABSTRACT

Awareness of the need to maintain existing urban infrastructure is increasing, yet people are worried about the mind-boggling sums required to correct the backlog of deficiencies.

The actions that must be undertaken by city engineers to translate infrastructure renewal needs into real programs is examined in this paper. Putting together a fabric, or framework, of material parts, that is, structuring the infrastructure involves not only technical competence, but money management, a goodly measure of awareness and understanding of political and public thought processes and a touch of innovation.

RÉSUMÉ

La population prend chaque jour davantage conscience qu'il faut entretenir l'infrastructure urbaine en place. Pourtant elle s'inquiète des sommes astronomiques requises pour remédier aux nombreuses faiblesses qui se sont fait jour.

L'exposé porte sur les activités que les ingénieurs civils doivent entreprendre pour traduire les besoins de renouvellement de l'infrastructure en des programmes concrets. Fabriquer un tout à partir de composants distincts - c'est-à-dire organiser l'infrastructure - suppose non seulement des compétences techniques, mais aussi une capacité de gestion financière et une certaine compréhension et appréciation de la façon de penser des hommes politiques et du public, sans computer un soupçon d'imagination novatrice.

A MUNICIPAL ENGINEER'S RESPONSIBILITIES

Usually the municipal engineer is responsible for the operation and upkeep of basic public facilities and services, all of which are now generally referred to as the infrastructure. As engineer for the City of Toronto, my duties and authorities are established by city council; these are rather extensive and are a good indication of the scope of experience and some of the skills required. The main responsibilities are as follows:

1. Design, construction, inspection, maintenance, and repair of public facilities such as roads, sidewalks, lanes, sewers, watermains, and bridges.
2. Management of public works operations such as refuse collection, snow removal, and street cleaning.
3. Development of long-term maintenance programs for basic services.
4. Maintenance of records of the projects and of the public facilities that come under the jurisdiction of the Public Works Department.
5. Preparation of plans illustrating the results of all types of surveys.

Some orderly and sustained work has taken place in the City of Toronto to organize the maintenance and reconstruction of all basic services. We have made an earnest attempt to structure our infrastructure by putting together a fabric or framework of all material parts.

No matter how well the work of inventory, condition assessment, priority setting, programme development, and project staging is carried out, those involved in urban management should give more than a passing thought to the mechanics of implementing plans. The successful practitioner must be alert and attentive to a few other factors such as:

- providing leadership to staff,
- managing the taxpayers' money,
- coping with political reality,
- relating to the public, and
- getting along with other levels of government.

LEADING AND INVOLVING YOUR STAFF

Put together and motivate a team dedicated to improvement, and the first step in keeping the infrastructure in good order has been taken. Create conditions and an atmosphere of productivity so that the staff can achieve their own perceived goals in that effort, and the potential of your staff will be developed so that your municipality will reap the rewards of energy, enthusiasm, and service. In these undertakings, it is paramount that the loyalty which your staff gives to the corporation be respected and returned by your own personal loyalty to them. In dealings with city council, for example, it is better that you have the courage to say, "I made the mistake." and not, "My staff made the mistake."

MANAGING THE TAXPAYER'S MONEY

Money for infrastructure projects, for the most part, comes from those who pay property taxes; what the taxpayer wants is value for money. Prepare budgets carefully, know them in detail, and stage them so that the programs can be readily understood and funded.

When it comes to determining just what the taxpayers' burden should be, I have real concern. I do not believe it is fair to place undue financial burdens on present or future generations and I subscribe to the equity of "user pay" for services required and received. In Toronto, two very important applications of this principle have been the sewage service rate and the sewer impost charge.

Sewer Service Rate

A sewage service rate is defined in the Statutes of Ontario as a charge for the operation and maintenance of sewage works, and includes a charge for depreciation and deferred maintenance, or a reserve fund for any such purpose and allows any municipality, by by-law, to impose such a charge. The average life of a sewer, properly maintained, is 100 years and therefore 1% of the depreciated or unexpired value of the sewer system seems to be a reasonable basis for reserve funding. Add to that amount the annual cost to operate and maintain the system and you have the total that can be charged as a sewage service rate.

A practical and fair way to levy such a rate is on the basis of water consumption -- a percentage surcharge can be applied as a separate billing on the water bill. In Toronto, provision is made to take into account those who use water from the City's system but do not use the sewer system; those who, through consumptive use of water, discharge less than they take; and those whose amount of discharged wastewater is greater than the amount of water taken from the City's water system.

In 1966, Toronto's sewage service rate was set at 22.7% of the cost of water consumed. This has been reduced over the years and the current rate is 15%. Since 1966, the total revenue from the sewage service rate has been in the order of $60,000,000. Accordingly, the money needed for the vital work of planned sewer maintenance has been free of "political tampering" when council decides on overall city needs and establishes the annual tax rate.

Sewer Impost Charge

The sewer impost charge is a fee levied upon the owners of highrise and other buildings that may impose a heavy load on the sewer system by reason of which expenditures are or maybe required to provide additional sewer capacity. Toronto's taxpayers faced a substantial cost for an extensive program for sewer replenishment, therefore a method had to be determined for direct-charging, a method which would apportion the cost of the construction program equitably. Toronto was no longer involved in the servicing of raw land, but was engaged in the re-servicing of lands whose current owners had every right to expect adequate sewer service. It therefore was inequitable for the taxpayer to bear the full brunt of the cost of the entire program.

Since modern urban construction increases the "waterproof" nature of the surface, thereby increasing peak rainfall runoff discharge to the sewers, a charge was developed accordingly.

Examination of runoff quantities and building development in the mid-1960s showed that new building construction was accounting for as much as 50% of needed increases in sewer capacity. A charge of $0.40 per square foot on new building construction at that time would have raised funds equal to about one-half of the city's new road storm sewer program. Council was concerned that such a levy would drive development away and instead decided to compro-mise and enact a charge of $0.20 per square foot. Later actions, through recommendations to City Council, brought the $0.20 charge to $0.40 in 1978 and to $0.50 in 1981. From 1966 to date, the sewer impost charge has raised more than $34,000,000, which represents about 20% of the net cost of sewer construction.

COPING WITH THE POLITICAL REALITY

We are fortunate in the City of Toronto that all business other than personnel and real estate matters is conducted in public. Members of the public and special interest groups can attend the meetings of the standing committees of council to depute, seek information, and ask questions. In addition, ward councillors and aldermen will arrange public community meetings from time to time in their wards. At these they request that senior staff from the department assist in answering questions that may come from the floor. In my view, these public airings are of immeasurable value, for they expose the officials to the desires, feelings, and moods of the public and the politician who represents them.

Over the years, senior staff of my department have attended some very stormy meetings, particularly after a rainfall flooded basements. These types of meetings are not pleasant for the politicians, who are generally assaulted with the fair question, "What are you going to do and when?"

When dealing with any problem of infrastructure renewal, officials should honour the commitments of the plan according to the plan. Any departure from these simple rules will cause the politician to lose confidence in you and ultimately lead to disregarding your proposals.

RELATING TO THE PUBLIC

A straightforward and effective public relations program is needed. Assuming that your works programs have been properly defined and are well-documented, the municipal engineer needs the ability to present them to a sometimes sceptical public. For instance, what can be done to convince local residents that you did not reconstruct the wrong street when it was obvious to them that some other nearby street which you did reconstruct was in better condition than their own? You know that the street is scheduled for sewer repairs in the coming year and complete reconstruction in 2 years, but unless the citizen understands this, the municipal engineer faces an uphill battle in eliciting the respect and confidence of the taxpayers. Work programmes must be documented clearly and they must be quickly and readily available to citizens and their political representatives.

Above all, the fundamental concern in relationships with the general public is consistency in fulfilling any commitments that have been made or implied in your programs.

GETTING ALONG WITH OTHER LEVELS OF GOVERNMENT

It pays to try to cultivate good working relationships with provincial and federal officials. In our dealings with the senior levels of government, we must be careful to avoid being categorized as just another in a long line of those begging for handouts. For example, under existing funding programs, the funding agency demands some evidence of need to justify and set priorities for grants. If you can present this information to them quickly, they are able to respond and allocate funds more quickly and equitably.

Requests for new funding programs must be preceded, or at least accompanied, by well thought out and justified programs and realistic staging. Demonstrate an ability to be part of the solution to the problem and, if possible, show that it is in their financial interest, albeit long term, to make the programs possible. For example, in Toronto, we have reduced the annual program for maintaining and reconstructing pavements substantially by developing and staging our own methodical management program. As far as the province is concerned, this has allowed them to reduce subsidies for Toronto and redirect available funds elsewhere. I live in hope of reciprocal favours.

A good working relationship with the officials of other municipalities is essential in cases where a project affects more than one jurisdiction. Some examples include waste disposal, transportation issues, and environmental concerns. If you have a reputation for fair dealing, well-researched positions, and the ability to work creatively towards solutions, then you will be much more effective over the long run in maintaining your municipality's best interests.

I am privileged to take part in the enterprise of translating plans to reality. Over the years, I have experienced changes in political desires and societal direction. I have "explained", for example, to many newly elected members through ten changes of city council, the whys and wherefores of Toronto's sewer replenishment programme. Those who have mooted new methods of approaching problems and their theoretical solution, have not always been kind. Numerous studies published by those who are not in the municipal "front line" have led to queries about effectiveness of the Toronto plan as it related, for example, to the abatement of polluting discharges. Despite all the hurly-burly, what I have learned boils down to something like this:

- have the temerity to start, no matter how uncertain and simple the start may be;
- bring together a small group of energetic colleagues and be single-minded in direction and purpose;
- endure the tedium and long hours of gathering, sorting and analyzing the field facts;
- decide on an affordable level of service and be mindful that it is the taxpayer who foots the bill;
- put the plan together, stage it sensibly, and propose fair methods for funding;
- broadcast the plan to the public and media and harness political support. (Don't tell fairytales about the plan, tell the truth no matter how unpleasant.);
- keep abreast of changes in technology, be ready to accept criticism, and try to be patient;
- Don't lose heart in the face of difficulties and, above all, keep a sense of humour!

UNDERGROUND PIPING SYSTEMS

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ABSTRACT

This paper outlines the logical steps necessary to properly implement and manage the rehabilitation of water distribution and sewerage systems.

These steps include the preparation of a system inventory according to defined terms, the actual detailed survey and inspection, the analysis of these surveys and the determination of needs, the subsequent repair, renovation and replacement programs, and, finally, the need for some institutional arrangements for managing the rehabilitation program.

RÉSUMÉ

Pour bien exécuter et gérer le réaménagement des réseaux d'aqueduc et d'égout, il faut, en toute logique, procéder de la façon suivante:

- dresser un inventaire des réseaux, en se fondant sur des critères définis;
- en faire une étude et une inspection poussée;
- analyser les résultats de cette étude et cerner les besoins;
- établir des programmes de réparation et de rénovation;
- prendre des arrangements pour assurer la gestion du programme de réaménagement.

INTRODUCTION

Implicit in the development, construction, and operation of a water distribution or sewerage system has been the universal need to create, from the initiation of its operation, a systematic, preventive maintenance and rehabilitation program to protect the substantial original investment. The program aims to avoid wastage of resources, undue wear, reduction or interruption of service and shortened system life expectancy.

Some of the components of public water distribution and sewerage systems are now more than 100-years-old, while the weighted average age of these systems in North America, is approaching 40 years. Evidence from recent studies (1,2) indicates that adequate maintenance and rehabilitation programs have not been established in many instances either due to lack of committed funds or inadequate management, or both. As a result, the adequacy of service can fall below that anticipated, and the life expectancy of the works from a physical point of view can become considerably shorter than intended.

Current replacement costs for municipal water distribution and sewerage systems have been estimated at $2,000 to $3,000 per capita, respectively (1). These considerable costs reflect the extensive and complex problem of replacing a fully operational network beneath an established main thoroughfare or under a well-developed residential community.

Experience in Britain and North America indicates that by instituting a regular, annual rehabilitation program at an average annual cost of 3/4 to 1% of the indicated replacement value, the life of these infrastructure systems can be extended to 100 years or more, thereby postponing expensive replacement costs indefinitely (2).

Much has been learned over the past 10 years regarding the rehabilitation of water distribution and sewerage systems. The initial British studies of the 1970s were followed by extensive research on the part of the British Water Research Centre, as well as field experience by municipalities throughout Europe and North America. The ultimate publication of the "Watermains Rehabilitation" and the "Sewerage Rehabilitation" Manuals by the British Water Research Centre (3,4) confirmed that a comprehensive infrastructure management system, as undertaken in the City of Toronto (5,6), can significantly reduce the high costs of rehabilitation estimated in initial reports (1,7).

It is therefore appropriate that upgrading and rehabilitation programs, from both a construction and management point of view, be instituted now to restore or maintain system worthiness. In undertaking a rehabilitation program, the work must be concentrated on the restoration of plant for improved and satisfactory customer service. Also, it must be sensitive to the availability of physical and human resources that can economically and practically undertake the restoration program.

It is recognized that larger municipalities may have the necessary staff to undertake the required work, while smaller municipalities may not. Smaller municipalities need to consider consulting and contracting services to substitute for lack of staff. The rehabilitation programs contemplated here are even more necessary and important to smaller communities than to larger ones and their sophistication should be no less than for any other system.

The components of the program can be best described as:

- the development of a database and inventory of piping system elements for the purpose of long-term planning of maintenance, repair, renovation, and replacement;
- a detailed survey-inspection by municipal or contract staff including leakage surveys, I/I detection, TV or photo inspection, smoke testing, and flow testing of water distribution and sewerag systems;
- an analysis or assessment of the deficiencies in the various elements of the system, the preparation of a priority rating of those elements requiring repair or renovation and their estimates of cost and the determination of the needed action, termed "the needs study";
- A systematic maintenance, repair, and renovation program of piping components based on the needs study and related to the database.
- A systematic construction program to replace deficient piping components that are beyond feasible repair or renovation.

A brief discussion on the requirements of each of these components, based on experience to date, follows.

TERMINOLOGY

Whether a municipality decides to create a fully computerized repair and management record or continues to keep a graphical block description and written record of its system and related repairs, it is important that a common method of identifying failure and condition, such as breaks and leaks, be established so that a technical analysis of these records can reveal trends and permit province-wide comparisons. These systems, as established by representatives of the Ontario Ministry of the Environment, the Pollution Control Association of Ontario, the Ontario Municipal Engineers Association, the Ontario Municipal Utilities Association, the Ontario Section of the American Public Works Association, and the Ontario Section of the American Waterworks Association are listed in Appendix A.

Also important in defining the manner of rehabilitation is a description of the various activities that must be undertaken. The use of these terms also permits comparison of the extent and cost of work between systems and from one year to the next. Again, these definitions were established by these same representatives.

Maintenance: The systematic survey, inspection, and cleaning of a sewer or watermain, including minor repairs, but not involving reconstruction of the main structural fabric or altering of the original dimensions.

Maintenance includes joint repair, renewal of manhole or valve chamber covers, steps or ladders, safety gratings, etc., and sealing cracks and leaks.

Repair: The repair of the main structural fabric of the sewer or watermain, including valve repair and the reconstruction of short lengths (10 metres or less), but not the reconstruction of the entire pipeline considered as an entity.

Renovation: The operation of effectively improving the condition of an existing sewer or watermain by in-situ techniques that will provide substantial increased life or efficiency. Renovation may or may not improve the structural strength of the pipeline.

Replacement: The construction of a new sewer or watermain in either the same location or a new location, so that the fundamental purpose of the original sewer or watermain will be incorporated into the junctions of the new conduit (this can include a portion of improvement for development), which may be designated as the same size or a different size.

The work described as repair, renovation, and replacement describes the rehabilitation of a watermain or sewer together with its ancillary structures so that it can continue to perform its originally intended purpose for a reasonable period of years.

INVENTORY

It is essential to the day-to-day operation of a water distribution or sewerage system that a sound database and inventory of piping system elements be available. Its existence is equally important to the intelligent planning and management of any program of rehabilitation in its initial and subsequent phases.

Most utility plans are prepared to various scales and systems. Many municipal utilities have developed general reference plans to permit ready location of detailed information from hardcopy files and have found such systems satisfactory. Unfortunately, these existing systems have no uniformity or consistency from municipality to municipality insofar as legends, details, scale, size, etc., are concerned. When a municipality is establishing an inventory where one does not exist,or is revising or expanding an existing inventory, serious consideration should be given to converting to the Ontario Basic Mapping Record System (or equivalent), as currently promoted by the ministry of Natural Resources, Consumer Relations, Health, and Municipal Affairs. Such conversion has served as the foundation for the preparation of rehabilitation programs for watermains and sewerage in Great Britain.

It is impractical to consider the initial cost of such conversion without other utilities, such as roads, transit, telephone, gas, and electricity, sharing in the costs. It is still practical, however, to create general reference plans supported by block plans that depict all system elements in detail, and that have been confirmed in description and location by field measurement. The confirmed and corrected data should be manually recorded by the appropriate reference system on file cards but preferably computerized. With the advent of the microcomputer, municipalities of all sizes can readily commit their systems both in detail and in summary to computerization. This conversion provides excellent summer work opportunities for student teams and should be strongly encouraged. All such work should be undertaken so that its information can be converted eventually and readily to the Ontario Basic Mapping Program (or equivalent) with the digitizing of all relative data from readily accessed computer files.

The block plan of each element should be designed to include at least the following:

- an identification code for each element,
- element type (pipe length, valve, meter, hydrant, service, manhole, catch basin, etc.),
- element class (trunk, arterial, local, private),
- location according to reference system,
- size,
- length,
- material with lining, coating,
- date of installation,
- burst or leak record and location,
- repair record (leak repair, relining),
- complaints reports (flooding, low pressure, etc.),
- soil type, bedding, cover, surface conditions, etc.,
- initial cost or replacement cost,
- cost of repairs by year,
- maintenance and service record (infiltration tests, flow tests, hydrant flushing, valve rotation, etc.), and
- condition rating. (See later commentary).

From such detail, the summary inventory data for systems as a whole or by section can be integrated and then manipulated to provide management intelligence as well as physical audit.

Costs for undertaking this component of the rehabilitation program have varied widely with size of municipality and the extent and detail of the records in existence. The provision of data based on a computerized inventory applied to the Ontario Basic Mapping Program will prove costly and expenditures of $50 to $60 per capita for municipalities of less than 10,000 persons, to $20 to $35 per capita with populations in excess of 100,000, have been encountered. These are one-time costs that can be expended, if necessary, over a 10-year time frame.

DETAILED SURVEY AND INSPECTION

Testing and inspection programs must be directly related to defining system deficiencies for repair and rehabilitation; but in the interest of good preventative maintenance, they should be addressed on a cyclical basis to ensure proper system performance as well as use. Crisis management should be avoided at all costs, because it leads to poor customer service and unnecessary repair costs. Programs related to hydraulic system analysis are not included here since they relate more to master plan development and update, and respond to overall planning and engineering procedures. They do benefit system operations, however, and can assist materially in assessing the value of rehabilitation alternatives.

Water Distribution Systems

The need for conducting leakage surveys, or unaccounted for water surveys, is constant. Some utilities base the interval of this survey on a preliminary rating of the system following inventory preparation and establishment of priorities based on age, pipe material, interruption of service incidents, repair history, pressure rating, etc. These are combined with water budget calculations to identify elements or blocks of the water distribution network that appear to account for major leakage in the system or major reduced pressure, and then proceed accordingly with their survey/inspection program. Other utilities, especially smaller systems, follow a constant regularized program intended to test and inspect a sufficient portion of the distribution system each year to ensure its integrity and service pressure, and to evaluate the need for repair or renovation. Such a program for systems of a weighted age of 30 years or more would suggest a cyclical program of testing and inspection to completely review the system at least every 10 years.

Methods that may be employed to reveal leakage and water loss, as well as tuberculation and loss of flow capacity, include sounding with various vibration detection equipment, pitometer surveys, fibre-optic internal examination, etc., all of which provide location and probable sources of leaks, as well as pressure loss and pipe constraints to flow. From this information a program of rehabilitation can be established.

The results of these surveys should be designed to provide the following data:

- leak or pressure loss survey identification code,

- date,
- coded number of pipe elements, hydrant, valve, meter, etc.,
- location of leak sounding or its siting (map reference),
- probable source of leak or unaccounted-for water and details of test results,
- pressure loss observations, and
- leak classification.

All of these data should be incorporated on the file card or the computer file of that element provided in the database inventory.

Based on 1986 figures within the boroughs of Metropolitan Toronto, the estimated costs of these surveys, including the costs of repairing the more routine leaks and water losses encountered, was $2150 per kilometer of main. Leak repair averaged $3,000 per break.

Sewerage Systems

The need for conducting sewer inspection and infiltration surveys also is constant. To check a sufficient portion of the system each year, most utilities follow an ongoing regularized program of sewer-cleaning and TV inspection with necessary repair or replacement so as to ensure its integrity and serviceability. A program of this nature suggests a cyclical procedure that would permit a complete review of the system every 15 years. Only cleaning is required at a more frequent interval.

The objectives of the inspection survey are to:

- establish the type, location, and flow rate of each significant infiltration/ inflow source;
- identify any blockages, or structural failures;
- provide a deficiency report giving detailed system condition data to permit the proper planning of a rehabilitation program.

The basic steps involve a physical, above-ground survey, smoke and dye testing, preparatory cleaning or, if necessary, reaming, internal close-circuit TV inspection, or visual walk-through surveys in larger sewers, infiltration and inflow isolation surveys, and a structural integrity analyses. The Manual of Practice ED-6 of the Water Pollution Control Federation, entitled "Existing Sewer Evaluation and Rehabilitation", contains a complete development of the process, as does the British Sewerage Rehabilitation Manual.

The estimated costs of these surveys (exclusive of repair costs)based on 1986 figures for 10,000 metres or more is $2.00 per metre for sewer cleaning, $25.00 per metre as a substitute, for sewer reaming, and $2.25 per metre for camera inspection.

NEED FOR STUDY

Repair and renovation should be predicated on the submission of a needs study report. The report is founded on information gleaned from the data base inventory and the deficiency report prepared as a result of the detailed survey and inspection. Each element in the system or "block" to be repaired is evaluated to establish the extent and detail of work required and its estimated cost.

To permit this, the inventory record for each element within the surveyed block is updated to reflect the results of leakage detection or I/I analysis plus physical inspection and evaluation of visible elements such as valves, meters, manholes, chambers, castings, etc. Where flow-testing or pipe inspection has been done, these data are also added to the inventory. Each element is then rated for condition, using a numerical system from 1 to 9 to establish its technical priority for need of repair:

1 - impossible or impractical to repair;
2 - repair only as a stop-gap measure;
3 - major renovation required which is consistent with remaining system life;
4 - major renovation required which is consistent with potential system life, needed now;
5 - major repairs justified (tolerance level rating)*, needed within 1 year;
6 - minor repairs required - normal wear and tear, needed in 1 to 2 years;
7 - routine maintenance required;
8 - no maintenance required; and
9 - recently constructed.

(* Tolerance level refers to the immediacy of repair.)

The decision to repair or renovate elements should be made by considering the overall needs rating of the block or system, and in conjunction with such external factors as:

- compatibility with current design standards,
- plans for system modification,
- planned reconstruction of other related infrastructure such as roads,
- potential risk of contamination or loss of service, and
- importance to system operation.

These factors may outweigh the technical priority for need of repair. In any case, a priority list for the correction of deficient elements in the system can then be prepared. No provision has been made here for assessing the need for watermain or sewer rehabilitation on a cost-benefit basis. Here the cost of repair and renovation would be measured against loss of treated and pumped water, increased sewage treatment plant flows, and energy wastage. The sophistication of such analyses does not necessarily respond to sound rehabilitation procedures.

Cost estimates are then calculated for the correction of each deficient element so as to include:

- labour,
- supervision,
- inspecting and testing,
- equipment and rentals,
- materials, and
- overhead factors.

Costs should be based on current rates and estimates suitably adjusted to the proposed construction time. Although replacement of all system elements will be required eventually, the needs study will disclose the elements requiring immediate replacement (rating of 1 or 2). In preparing the cost estimates of these replacements, due consideration should be given to credits for the salvage of materials, if any; the cost of the demolition; and the cost of providing temporary services. The cost of this analysis can be best estimated as a percentage of the value of the detailed annual survey and inspection of the systems according to system size, i.e., for systems serving 2500 persons or less: 10%; over 10,000 persons: 5%.

REPAIR AND RENOVATION PROGRAMS

Water Distribution

The major renovation program generally required in the rehabilitation of watermains relates to restoring flow capacity. Internal tuberculation buildup or pipe lining failure increases friction factors, thereby reducing dramatically the hydraulic capacity of the main. The problem is normally corrected by reaming the main and the application of a protective cement mortar or plastic lining. This problem normally is associated more with older, unlined cast iron and ductile iron mains. Present-day practice is generally to use PVC pipe or to provide this lining at the factory, before installation, to eliminate the problem altogether.

Normally the work is carried out by first constructing a temporary surface line to provide continuing service to the water customers while the main is under renovation. Then pits are dug at 1000-metre maximum intervals to gain access to the main. Each 1000-metre section is then shutdown and divided into at least three sections to allow concurrent cleaning in one section, lining in the second, and curing and chlorinating in the third. In order to provide access to each section, a short piece of pipe, less than 3 metres, is cut and removed from the main. After all pipe work has been completed, the short pieces are cleaned, lined, replaced in the main and secured with repair clamps.

Cleaning is usually done by dragging a cleaning tool attached to a cable through the line to remove tuberculation. The cleaning tool is simply a series of scrapers, similar to paint scrapers that are made of spring steel and arranged radially around a core. The springing action keeps the scrapers in constant contact with the internal surface of the pipe as the tool is pulled through the line. After thorough cleaning, the line is flushed and a circular squeegee is pulled through the line to remove debris and water from low spots in the pipe.

Cement lining is done by pumping mortar through hoses to an application machine that is pulled through the pipe. The application machine throws the mortar onto the internal pipe walls. A trowelling device is attached to the back of this machine to distribute lining material evenly, leaving a smooth finish. Plastic inserts may be substituted for cement lining, but their application as yet appears less reliable.

The entire operation, including the temporary service main, is usually undertaken by one contractor. Based on 1986 prices for 10 kilometres or more, it costs about $110,000 per kilometre. Service replacement generally cost from $2000 to $3000 each, whereas break or leak repairs run to about $2500 to $3500 each. Canadian experience in the British processes of slip lining and moling is virtually non-existent, so no estimates are available for these alternatives.

Sewerage

The reduction of infiltration/inflow into sewerage systems, and the repair of structural inadequacies through rehabilitation, is a critical aspect of system management. The technology and benefits associated with a sound rehabilitation program are well established, but the application systems are changing constantly, mostly as a result of British experience.

When the sources of infiltration/inflow are leaking pipe joints and the sewer pipe is otherwise free from such defects as major cracks, the joint leakage can be reduced and sometimes eliminated by chemical grouting or pressure pointing the joint with elastomeric material.

Deteriorated pipes may be replaced with new pipes or lined by inserting a pipe lining of glass-reinforced plastic, polyolefins, or employing a unique sleeve lining, "insituform". Also, segmental linings of glass-reinforced cement, glass-reinforced plastic, precast gunite or polyester resin concrete may be used in larger sewers. Sprayed gunite, reinforced or unreinforced, may also be employed in lateral sewers.

All these systems require particular expertise. Some are patented, but all can be undertaken with traditional sewer contractors' forces supported by an experienced advisor.

Some insertion sleeves or liners are not structurally capable of carrying the same loads as standard sewer pipes and cannot therefore be used in areas where the pipe barrel is structurally unsound.

Manholes are frequently a major source of infiltration and inflow and may have to be raised as well as sealed to control the extraneous flow.

Removal of unauthorized connections is another major area for reducing direct entrance of stormwater to sanitary sewers.

Finally there is increasing evidence that a major part of infiltration can be attributed to service connections. Although these are normally repaired by excavation and replacement, several sophisticated systems of internal sealing, that do not require excavation of the connection are available.

In all of the foregoing, of course, no lining of the sewer can be undertaken before a thorough reaming of the barrel is done to create a concentric form with which to work.

Based on an average diameter of 250- to 300-mm, unit costs of sewer renovation for 1986 are as follows:

	Materials	Reaming	Labour	Total (per meter)
Pressure Grouting	$ 5.00	$25.00	$95.00	$125.00
Chemical Grouting Joints	$10.00	$25.00	$80.00	$115.00
Plastic or Mortar Lining	$25.00	$25.00	$175.00	$225.00
Polyethylene Pipe Insertion	$75.00	$25.00	$125.00	$225.00
Service Relining	-	-	-	$800.00(Unit)

On the whole, sewerage systems seem more adaptable to renovation rather than replacement programs, probably due to the fact that they are not under pressure and access to them is more easily gained than to watermains.

The renovation program varies widely in the type of remedial work required. Most sewers would require some form of sealing, while a few require relining in some form.

Similarly, services now can be renovated through unique relining programs to reduce substantial infiltration and, according to experience to date, about one-third of services would have to be restored.

REPLACEMENT PROGRAM

Finally, there is the residual replacement program required which embodies the construction of a new watermain or sewer either in the same location as the existing facility, or in a new location so that the fundamental purpose of the original sewer or watermain will be incorporated into the functions of the new conduit which may be constructed of the same size or of a different size.

This program of systematic replacement relates to deficient piping components that are beyond financially viable repair or renovation.

Water Distribution

In the case of water distribution, replacement relates to pipe elements that have deteriorated through extensive corrosion either internally or externally, or pipes that have been exposed to considerable ground shock or settlement and are evidencing abnormal breakage and repair rates. In such instances, the complete replacement of all main appurtenances, including valve and hydrants, usually are required. Either ductile iron Cl 52 or PVC DR-18, Cl 150 would be used.

Based on an average diameter of 200 mm the estimated cost ($,1986) of replacement, assuming paved surfaces, solid sheeting and the use of unshrinkable backfill, is about

- $150,000 to $225,000 per kilometre,
- $1500 to $2000 per hydrant,
- $3000 to $3500 for valve and chamber, and
- $2500 to $3500 per service.

Sewerage

In relation to the replacement of elements of a sewerage system, renovation is required as a result of structural failure of the pipe barrel, major misalignment through settlement and major deformation and reduction of hydraulic capacity. In these instances the complete replacement of all sewer appurtenances, except pumping stations usually is required.

Based on an average pipe diameter of 250 to 300 mm, the replacement value is estimated according to 1986 prices, assuming paved surfaces, solid sheeting, and unshrinkable backfill, at

- $225,000 to $275, 000 per kilometre,
- $2250 to $2750 per manhole, and
- $3000 to $4000 per service.

INSTITUTIONAL ARRANGEMENTS

It is important to recognize that the institutional arrangements governing the administration, management, and finance of a waterworks or sewage works are critical to the success of any rehabilitation program in providing maximum system life at least cost as well as customer satisfaction. Obviously, some agency has had the responsibility for the planning, initial design, and construction, as well as the operation and maintenance of the facilities now to be rehabilitated. A thorough management study should be considered to determine whether the utility is properly structured to undertake the rehabilitation program, or whether improved management systems are required before embarking on such a program.

Also, public interest and education in the need for the project, its benefits to the public health, the anticipated improvements in customer service, and the optimum mode for operating the improved facilities will be necessary to foster local support. The on-going aspect of ensuring that the day-to-day operation of the revamped or expanded system is satisfactorily undertaken, and that an appropriate rehabilitation program is continuously maintained over the planned life of the rejuvenated system, is essential to the investment.

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APPENDIX A
WATERMAIN FAILURES - TYPES AND CAUSES

Types of Failures

1. Pipe:	1.1	Circumferential Crack (ring break)		____
	1.2	Longitudinal Crack		____
	1.3	Wall Holed (corrosion)		____
2. Joint:	2.4	Joint Failure/Leak		____
3. Appurtenaces:	3.1	Valve Failure/Leak		____
	3.2	Other		____
4. Fittings:	4.1	Fitting Failure/Leak		____
5. Services:	5.1	Service Saddle		____
	5.2	Main Stop		____
	5.3	Curb Stop		____
	5.4	Service Leak/Failure		____
6. Pipe Condition:	6.1	Tuberculation	- Light	____
			- Medium	____
			- Heavy	____
	6.2	Pitting	- Light	____
			- Medium	____
			- Heavy	____
7. Chambers	7.1	Require Repair Work		____
	7.2	No Work Required		____
8. Probable Causes of Failure:	8.1	Construction Activity (damage by others)		____
	8.2	Frost		____
	8.3	Vibration		____
	8.4	Improper Tapping		____
	8.5	Corrosion/Electrolysis	- Clay	____
			- Other	____
	8.6	Loss of Suppoirt/Bedding	- Erosion	____
			- Settlement	____

APPENDIX A

SEWER CONDITION CLASSIFICATION

Description

1. Collapsed
2. Irregular Line/Grade
3. Calcite Buildup - heavy
   - average
4. Tree Root Penetration
5. Protruding Laterals
6. Cracked Pipe (No Displacement)
   (a) Ring (circumferential)
   (b) Longitudinal
   (c) Spiderweb
7. Cracked Pipe (Displaced)
   (a) Ring
   (b) Lonitudinal
8. Corrosion of Surface
9. Satisfactory
10. Manholes - require repair
    - no work required

Probable Causes of Defects

1. Age of sewer
2. Improper bedding/foundation
3. Improper backfill
4. Corrosive environment (low PH)
5. Construction Activity
6. Pipe Material (Type)
7. Unknown

PROSPECTS FOR DISTRICT HEATING AND COOLING IN TORONTO

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ABSTRACT

Interest in district heating systems is being rekindled in North America because, compared to on-site heating systems, they offer:

- price advantages;
- revitalization of commerical and industrial areas; and
- fewer problems with air pollution.

Part of the downtown area in the City of Toronto is served by such a district heating system, and its success has spawned plans to extend this service to another part of the downtown area, and to incorporate it in the development of a major commerical complex.

RÉSUMÉ

Les systèmes de chauffage de district éveillent à nouveau l'intérêt en Amérique du Nord, car ils offrent plusieurs avantages que les systèmes exclusifs à un établissement n'ont pas. Aiasi, ils permettent:

- d'épargner des frais,
- de revitaliser les secteurs industriels et commerciaux et
- de diminuer la pollution de l'air.

On a installé ce genre de système dans une partie du centre-ville de Toronto et les résultats obtenus sont tels qu'on envisage maintenant d'étendre le service à un autre secteur du centre-ville et de l'intégrer à un grand complexe commercial en construction.

If this conference were being held in Europe much of its time would be devoted to the maintenance of district heating systems utilities that provide hot water or steam for space heating from central sources via networks of underground pipes. In most of Europe's northern cities the municipal investment in the infrastructure of heating plants, pumps, pipes, and heat exchangers is substantial. An example is the Copenhagen region of Denmark, where $700 million is being spent to integrate the district heating systems of 16 municipalities. Across the Oresund is the City of Malmo, Sweden, there the district heating system extends for 400 kilometres and serves 90% of the population.

Five or six decades ago, there was more installed district heating capacity in North America than in Europe. After 1945, inexpensive fossil fuels and the shift in development to lower-density suburbs made district heating less attractive to North American municipalities and developers. The systems were abandoned. In Europe, however, fuel costs and development densities remained high. The post-war reconstruction of Europe included installation and expansion of extensive district heating networks, whose growth continues. Now, for example, about 50% of space heating in Sweden is provided by a district heating system, compared with about 1% in Canada. The success of district heating in Europe is rekindling interest in North America.

This interest is being aroused by three factors:

- Current and anticipated prices favour district heating over on-site systems. The clearest evidence of the profitability of existing district heating systems is private-sector interest in taking them over, which has happened in six cities in the United States.
- Municipalities are beginning to see district heating as an attraction in the revitalization of commercial and industrial areas. For example, in Minneapolis, the city-run system is used to promote the area it serves to new business.
- Environmental considerations favour district heating systems. Compared with on-site systems, stack emissions are up to 75% lower in the case of nitrous oxides. Also, cross pollution from the stack of one building to the air intake of another believed to be a factor in some cases of "sick-building syndrome" is avoided.

The city in North America with the greatest potential for expansion of district heating is Toronto, where a new development, equivalent in area to more than half the amount in the existing downtown is planned for an adjacent 80-hectare area, the Railway Lands. This paper first describes the present district heating system in Toronto and its management. It then sets out the proposals for district heating and district cooling in the Railways lands and adjacent areas.

THE TORONTO DISTRICT HEATING CORPORATION (TDHC)

This provincially-chartered public corporation, established in 1984 on the initiative of the City of Toronto, is a partnership among institutions with an interest in the heating of buildings in downtown Toronto: the City of Toronto, the Government of the Province of Ontario, the University of Toronto, and four hospitals. These interests are represented on its 10-person board of directors, which also includes a representative of the TDHC's commercial customers.

The system managed by TDHC meets the demand for space heating and hot water of some 150 buildings in downtown Toronto, of which about half are commercial buildings. It also provides a reserve supply of steam for the extensive system operated by the University of Toronto. The TDHC system was formed from the following:

1. A system serving some 75 commercial customers from the Pearl Street steam plant, managed by Toronto Hydro;
2. A system serving four downtown hospitals from the Walton Street steam plant, managed by the Toronto Hospitals Steam Corporation;
3. A system serving the Queen's Park complex of the Ontario Government from a steam plant in the Macdonald Block, managed by the Ministry of Government Services; and
4. A system serving the University of Toronto.

The four systems have been integrated. The first three have come wholly under the management of the TDHC. The University of Toronto system is managed separately and served from its campus plant, but has a trading relationship with the TDHC system. The Walton Street plant serves as the base plant for the TDHC system, with the Pearl Street plant as a peaking plant. The plant in the Macdonald Block was closed after a boiler explosion.

TDHC will soon begin providing steam to the remaining district heating system in Toronto, the one run by the Toronto Terminal Railways Company which serves the Royal York Hotel, Union Station, and other buildings south of Wellington Street.

Integration of all five systems was proposed in 1973 by Ray Bremner, the City of Toronto's Commissioner of Public Works, and endorsed by city council in 1974. The objectives were to provide more efficient operation of the systems and to allow for the use of inexpensive steam from a single refuse-fired plant that would replace the Pearl Street plant, which has been under order to close since 1968 on account of the impingement of effluent from its stack on nearby buildings. In 1979, the City purchased an 11-hectare site for the plant at Cherry Street and Lakeshore Boulevard.

In 1984, the board of directors of the newly formed TDHC subscribed to the proposal to use energy from waste as a means of reducing costs and enabling TDHC to compete with on-site heating installations. By 1987, TDHC had become competitive without the refuse-fired plant, the result of efficiencies in operation, a cost-effective upgrade of the Walton Street plant, an expanded customer base, and an advantageous contract with a producer of natural gas in Alberta. (The first long-term contract for heating signed after the federal government's deregulation of natural gas distribution.) The resolution supporting construction of a refuse-fired steam plant nevertheless remains in effect.

DISTRICT HEATING AND COOLING IN THE RAILWAYS LANDS

As approval of the new Official Plan for the Railway Lands approached finality during 1986, TDHC began to consider its opportunities in this 80-hectare undeveloped area immediately southwest of the downtown area. Development of this area, equivalent to about half the amount presently in the downtown area, is planned for the next 20 years. Section 9.6 of the Official Plan for the Railway Lands reads as follows:

> Council will seek to ensure by, among other things, the use of its powers under Section 40 of The Planning Act that development in the Railway Lands is energy efficient. To this end, it is the policy of Council to work with the Toronto District Heating Corporation to encourage the development of district heating and cooling systems within the Railway Lands.

Two preliminary feasibility studies into district heating and cooling in the Railway Lands and adjacent areas were conducted by Engineering Interface Ltd. They gave rise to the following conclusions:

1. Developers of real estate in the Railway Lands and adjacent areas have indicated willingness to connect to central heating and cooling plants if the capacity is well reinforced against outage, and the cost is the same or lower than that of on-site systems.

2. A more precise identification of potential customers has revealed a slightly smaller potential for both district heating and district cooling, in terms of floor area that could be served, than a previous estimate. However, more precise delineation of costs and benefits has indicated greater advantages than before for district heating and district cooling in terms of capital and operating costs. Capital investment would be $4.30 per square metre less for district heating and $10.75 per square metre less for district cooling; annual operating costs would be up to 16% less for district heating and up to 13% less for district cooling.

3. A major problem is finding a location for the 125-metre chimney stack required for the heating plant. This can be mostly concealed inside a tall building. The

first suitable building will be the 120-metre office tower planned by Canadian National Realty for construction just southwest of the site of the domed stadium. It is scheduled for completion in 1991.

4. A start on planning for a central heating and cooling plant must be made without delay if the opportunity is to be seized.

A steering committee of city officials and others was established by city council in December, 1986 to supervise the work of Engineering Interface Ltd. In February, the steering committee was authorized by council to negotiate locations for a stack and a plant and to report on who should have carriage of the proposal.

These negotiations are continuing. The outcome sought by the steering committee has the following components:

1. The plant will be located in a vault beneath the plaza and underground parking lot to be created by Canadian National at the southwest edge of the domed stadium. The stack will be located in the first office building to be constructed on the Railway Lands, which will be a building on Canadian National land immediately west of the stadium.

2. The City of Toronto will pay for and own the vault and the stack, and thus will be the landlord of the core of the proposed system. This arrangement has been agreed to in principle by city council.

3. TDHC will pay for construct, and own the heating and cooling distribution systems.

4. Proposals will be solicited to design, build, and operate the heating and cooling plant. The most important criteria for evaluation of the proposals will be the prices charged for hot and chilled water and the amount of rent paid to the City of Toronto. Important subsidiary criteria will be the ability of proponents to accommodate energy sources other than natural gas. Two such sources are being discussed. One source is hot water from a refuse incinerator that the Metro Toronto Council (which is responsible for waste disposal) may construct west of the downtown. The other source is chilled water drawn from Lake Ontario at depths below 80 metres, where the water is permanently at 4° C, through a 6-kilometre tunnel, 3 metres in diameter, below the lake bed, the Freecool proposal. Further considerations will be the extent to which cogeneration and parallel generation of electric power are part of the proposal, and the disposition of the plant at the end of the agreement. Proponents will be expected to design and cost the distribution systems.

5. Initially, preliminary proposals will be invited. Four bidders will be selected to prepare final proposals, each being paid $50,000 for the work.

6. The costs of the final proposal stage, including payment of the bidders, will be borne jointly by Canadian National, Marathon Realty (the real-estate arm of

Canadian Pacific, the other major landowner in the Railway Lands), Metro Toronto, and the Ontario Ministry of Energy. Three of these potential contributors have agreed in principle to provide a portion of the funds. Construction of the vault and the call for preliminary proposals should all begin during the summer of 1987.

The total investment contemplated for district heating and cooling in the Railway Lands and adjacent areas of Toronto during the next 20 years is more than $100 million in 1987 dollars, including Freecool and the connection to a refuse incinerator. Care must be taken to ensure that this investment, if it is made, will be properly protected by adequate maintenance.

AN IRREVERENT LOOK AT URBAN INFRASTRUCTURES

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ABSTRACT

To renew an urban infrastructure it is also necessary to look at the entire urban structure because the problems that we have to solve are not solely related to the infrastructure itself. Infrastructure, perhaps, pose fewer problems than the indeterminate nature of the urban structure itself. Furthermore, all these issues are interrelated.

RÉSUMÉ

Au moment de renouveler une infrastructure urbaine, il faut nécessairement tenir compte de l'ensemble de l'organisation urbaine, car les problèmes à résoudre ne tiennent pas seulement à l'infrastructure même. ∂De fait, celle-ci pose sans doute moins de problèmes que le caractère indéfini de l'organisation urbaine. De plus, tous ces éléments sont interdépendants.

To say that the urban infrastructure is a reflection of the urban structure that it serves is perhaps redundant, yet it is often forgotten in solving problems concerning infrastructure. We frequently try to deal with these problems as if they were independent of the problems that beset urban structure. Our attitude towards urban structure greatly affects the demand for urban infrastructure and many problems arising from the infrastructure can be traced back to those of the urban structure.

Due to financial restraints, maintenance of the urban infrastructure is reactionary - it reacts to, rather than predetermines problems. For example, Mississauga, a community of nearly half-a-million people, was built without sufficient rights-of-way to serve it with a public transportation system more adequate than the cheap, makeshift arrangement currently being provided. There are many reasons for this: economic, political, lack of foresight, etc. One cannot upgrade an existing infrastructure to the highest technical standards if the future and changes it brings to the urban structure were not anticipated. If the results were not so far-reaching - and often tragic in their outcome - what is happening at the moment could be considered a comic interlude.

As I watched my street (Beaumont Road) being newly paved after 20 years of neglect, I could not but feel a great sense of joy in seeing that beautiful new road bed. But my joy was short-lived because I had to watch a few days later with dismay as Consumers Gas started to frantically dig a trench to find something. To my amazement, this trench did not follow the geometry of the road but managed to criss-cross the new road bed several times. The ensuing patchwork destroyed some of the original beauty, but I endured it. I felt like someone who had bought a new suit and ripped it on the second day, but who then resigned himself to its invisible mending - which is, of course, not invisible. But that was not all. In sebsequent months, two other services attempted the same exercise, only their criss-cross patterns were in the opposite direction from the previous ones, and within 4 months the road looked worse than it had prior to its new paving job.

With the construction of the Eaton Centre theme arose a public worry that the interior mall might disturb the life of Yonge Street. To make sure that this would not be so, about 30 stores were opened up onto the street so that today, in fact, pedestrian activity on Yonge Street is greater than before. To improve Yonge Street generally, we felt that beautiful shade trees would create a Parisian boulevard-like appearance. In short, we wanted to create an enjoyable urban structure. When we were about to plant these trees on Yonge Street, however, we were told that every inch of sidewalk was allocated as a right-of-way for the many services needed for the infrastructure: lines for telephone and electricity, pipes for gas and water, etc. The policy was to put as many of them under the sidewalk as possible. Trees would be intruders in such a situation; their planting was to be eliminated from the plans. We were told to put them in little pots on top of the pavement! The advantage it was said, was that they could be carted away when they were not needed. I wonder how Paris would look if we chopped all the trees there down and put miniature ones in little pots along the Avenue des Champs élysées. After endles pleading with the mayor and the Metro chairman, Cadillac (the developer) finally was permitted to plant a few trees in the ground. But only on condition that pots would be sunk into the ground, so that the roots could never interfere with the necessities of the infrastructure. In the ensuing 10 years, the wonderful maple trees that were planted did not quite understand the necessity of living under such conditions, and one after the other has died despite attempts to bring new reserves into action; an attempt which, by the way, is still ongoing.

The question I want to ask is this: Is there no room for compromise? Is the urban infrastructure not there to serve the urban structure and the life it should sustain? Should we not first attempt to create the best possible urban structure and then serve it, rather than the reverse? How does Paris manage it? I often wonder whether the genius that created the Parisian underground system nearly 100 years ago also could be applied in our planning. Would it not be possible to have an accessible service system in which all services could be conveniently located, particularly in the dense downtown, and which could also allow trees to grow? I am positive that the life-cycle costs of such a system would be far less than our present methods of digging and disturbing.

The urban infrastructure is quite analogous to the infrastructure of a large building complex. When, for example, we built the McMaster Health Sciences Centre, we studied a great number of health buildings and studied the research done by Ehrenkrantz in California in which he established that the adaptation costs of Health Sciences buildings at the University of California over the last 30 years was nearly 300%. In other words, the University could have torn all these Health Sciences buildings down every 10 years and rebuilt them without having spent any more money.

With that in mind, we attempted to build a complex in which this would not occur. In a health sciences building nearly 50% of the costs are related to mechanical and electrical services. We wanted them accessible and renewable in a manner that would not destroy the building itself. So, rather than burying the services in walls and ceilings, they were placed in accessible interstitial spaces. The result over the last 15 years has been phenomenal, yet little or no attention has been paid to it. This is because we are not in the habit of comparing operating costs, maintenance costs, and adaptation costs. I think the savings in life-cycle costs of such an approach are huge, yet the true life-cycle costs are known today for only a few hospitals.

The issue is even more complex: within 2 years the operating costs of a health sciences centre match the initial capital costs. An outdated facility can increase these operating costs drastically and, of course, vice versa. Unfortunately, the social and financial consequences are never really considered.

The same problem faces us in the evaluation of the urban infrastructure and its relation to the effectiveness to the urban structure. Let me give you one other example -- that of Toronto's airport and its relation to our urban transportation system. Both have been conceived as if they had nothing to do with each other. The resulting social costs to a city such as Toronto are phenomenal; the time and the cost of moving people by taxis and limousines, who easily could be moved by mass transit, not only is a waste of the man-hours spent by the passengers, but also of the man-hours that are needed by the people who operate these vehicles, the road system that is required to move these vehicles, etc. Not only have we never made a serious attempt to bring a public transportation system to the airport, we are now expanding the airport with no solid concept of where such a system could be located.

I think that many of our urban problems reach back to the concept of modern urban planning and the love/hate relationship it had between country and city; the city that, in fact, had been quite skilfully developed during the early industrial period, yet was still rooted in its predecessor, the preindustrial city. Both the industrial and the pre-industrial city by necessity lived on the rule of density. The walking distance, even after the introduction of the railroads, controlled the condensation of an urban environment.

The development of the American city, particularly after World War II, was quite anti-urban, following modern guidelines and the apparent freedom that the automobile seemed to offer. The result was the demise of the urban downtown. Nobody has described the symptoms better and identified the problems of such wrong planning theories than Jane Jacobs in her book, The Death and Life of Great American Cities.

We have realized again that the lively downtown, the mix of uses, the functional and visual enjoyment of the downtown are important ingredients. Those cities that have followed these imperatives have been successful. The problem we still are facing, however, is that we have not fully understood the inter-relationship of these issues with the economic motor that keeps the urban environment alive. Perhaps one of the most illuminating books written lately on this issue is Jane Jacobs', Cities and the Wealth of Nations. In it she demonstrates that it is the urban centres that create the wealth of a nation. At present, however, we have an economic system that negates this reality and siphons away from the city its financial power, which it needs to create new wealth, for example, the problem of not having sufficient money to create the necessary infrastructure to make the urban structure effective.

Many of the articles presented here today clearly indicate the neglect of these issues. Recently, a big argument arose concerning the necessity and the lack of financing for a new transit line in Toronto's Harbourfront area. The expenditure of $100 million that will be needed to put a modest urban transportation system there is felt to pose a problem for the community. Yet the new wealth that such a system would create bears no financial relationship to the cost of its creation since the introduction of such a transit system would permit the addition of approximately 10 million square feet of office space in that area. This would incur to a conservatively estimated increase in wealth of close to $0.5 billion. Thus, if the city could sell the rights for this density, it could recover the cost of the system more than five times over. (Perhaps the example is overly simplistic because it ignores other reasons for such a decision, but it is indicative of the present problem of relating the availability of municipal income to municipal expenditures.)

We must recognize that questions concerning urban infrastructure are directly dependent on decisions relating to the urban structure. We also must consider the totality of urban problems and their relation to each other. I have not attempted to outline solutions to our problems but merely pointed out the discrepancies that currently plague our system.

Behind my anecdotes lie six serious neglects that could be fatal to urban life if not taken into consideration:

1. The lack of integrating the different facets of the urban infrastructure, which I tried to demonstrate in the sad but true saga of Beaumont Road.
2. The conflict between the infrastructure and the urban structure as demonstrated by the trees outside the Eaton Centre.
3. The lack of life-cycle costing in the arrangement of infrastructure, as in the example of McMaster.
4. The lack of social life-cycle costing, as in the example of Toronto's airport.
5. Outdated urban planning theories and their influence on the urban infrastructure.
6. And finally, outdated economic theories and their disastrous stranglehold on the financial health of the city.

NEW CONCEPTS FOR UPGRADING WASTEWATER TREATMENT PLANTS

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ABSTRACT

The Federation of Canadian Municipalities (FCM) survey suggests that expansion and upgrading of sewage treatment systems will require 11% of the total expenditure on urban infrastructure improvement. Controlling this expenditure will require that maximum use be made of existing facilities. The wastewater treatment process audit represents a tool which can be used to assess the condition of existing facility, identify the hydraulic and process bottlenecks and establish the actual capacity of the existing plant. Two examples of process audits undertaken at municipal treatment facilities are described, with particular emphasis on the impact of the data collected during these audits on the expansion plans for these facilities.

RÉSUMÉ

Lorsque la Fédération canadienne des municipalités a étudié l'état de l'infrastructure des villes canadiennes et des fonds affectés à ce poste, elle est arrivée à la conclusion qu'il faudrait dépenser 6,3 milliards de dollars pour améliorer l'infrastructure municipale de 33 villes de plus de 100 000 habitants. De ce montant, environ 710 millions de dollars devraient être consacrés aux installations de traitement des eaux usées, qu'il semble en général plus nécessaire d'agrandir que de réparer ou de remplacer.

Les plans des usines de traitement des eaux usées ont jusqu'ici été de conception très traditionnelle, reflétant l'état de la science en ce qui concerne les procédés biochimiques et physiques complexes employés dans ces installations. Aujourd'hui, la disponibilité de meilleurs instruments en direct et de matérial de commande microinformatisé permet de dessiner les installations de traitement des eaux usées de façon à maximiser la capacité des usines en place. Ces instruments en direct et ce matériel d'acquisition de données peuvent également servir à cerner les restrictions de capacité et à garder au minimum les dépenses d'immobilisations nécessaires, en rationalisant l'emploi des installations en place.

Les résultats de la vérification de cinq usines de traitement des eaux usées permettent de démontrer les avantages possibles d'une telle méthode, du point de vue économique et au plan du rendement.

INTRODUCTION

Rapid urbanization in Canada in the 1950s and 1960s resulted in the expansion of the public works facilities required to support urban communities. This urban infrastructure needs to be maintained and occasionally expanded to ensure that the requirements of the communities it serves continue to be met. Concern for the condition of Canada's urban infrastructure prompted the Federation of Canadian Municipalities (FCM) to undertake a survey identifying funding levels and requirements as a basis for the development of policies to correct any inadequacies (1). The survey included all FCM member municipalities and focussed on the following public works facilities (2):

- separate and combined sewer systems,
- sewage treatment facilities,
- water distribution systems,
- water supply, treatment, and storage facilities,
- roads, and

- bridges.

This paper deals with the sewage treatment component of urban infrastructure and specifically discusses an approach which has promise for maximizing the capacity and capability of existing infrastructure.

CONDITION OF WASTEWATER TREATMENT FACILITIES

The 1984 FCM survey identified that 62% of the municipalities which responded placed sewage treatment facilities as the highest priority for expenditures (2). The preliminary per capita cost of bringing these facilities up to an acceptable level was estimated at $89 ($,1983), a cost equivalent to 11% of the total per-capita cost to upgrade the six public works facilities listed in the introduction, which was estimated at $790 per capita (3). That means that the total cost to upgrade sewage treatment facilities in 33 Canadian cities with populations over 100,000 is calculated to be approximately $500 million.

The FCM survey (l) showed that the average age of sewage treatment plants in Canadian municipalities was 15 years, compared to 30 years for sewers and watermains, and 22 to 23 years for roads and bridges. Sewage treatment facilities also were identified to be generally in good physical condition. These findings lead one to infer that the high priority placed on sewage treatment plant expenditures likely reflected a need for expansion more than a need for repair and replacement (2).

Recent evaluations of the status of sewage treatment facilities in Ontario support this inference(4). For example, it is projected that, by 1991, the total existing hydraulic capacity in treatment plants that are larger than 4,546 m^3/d and that discharge to the Lake Erie drainage basin will be exceeded if the present rate of flow increase continues. In the Lake Ontario and St. Lawrence River drainage basin, almost 20% of the sewage treatment facilities were operating above their hydraulic design capacity in 1985, and it is projected that at the present rate of growth, the existing hydraulic capacity of all plants in the basin will be exceeded by 1997.

Other pressures for sewage treatment plant expansion result from the inability of existing facilities to comply with their discharge requirements, and from the imposition of more stringent performance requirements on existing facilities. Recent data for Ontario showed that 25% of the 403 municipal sewage treatment plants failed to meet the Ontario Ministry of the Environment guidelines in 1985 (5). Widespread enactment of tighter guidelines on the discharges from these facilities will further increase the number of non-compliant plants.

The traditional approach taken in sewage treatment plants nearing hydraulic capacity which, therefore, have difficulty meeting existing performance requirements or are subject to new, more stringent performance standards, has been capital-intensive plant expansion. This philosophy is reflected in the results of the FCM survey. But unlike other elements of urban infrastructure, which have a relatively narrow and inflexible range of capacity, sewage treatment plants incorporate physical, physical-chemical, and biochemical processes that may be optimized to provide adequate service beyond their conservative design ranges. Often the decision to expand a facility does not consider adequately such process optimization.

An assessment tool which can be used to evaluate an existing treatment plant, and to identify avenues to process optimization is the wastewater treatment process audit. In some cases, such process audits can minimize or forestall the capital expenditures associated with major plant expansion.

WASTEWATER TREATMENT PLANT PROCESS AUDIT - THE APPROACH

The original developmental work on the wastewater treatment plant process audit was done at Environment Canada's Wastewater Technology Centre in Burlington, Ontario. The initial efforts were aimed at developing a monitoring tool that could be used to estimate the energy savings potential achievable through on-line control of the energy-intensive oxygen transfer processes used in these wastewater treatment facilities. The capability of the audit approach to predict energy savings was demonstrated at the Tillsonburg, Ontario, water pollution control plant (WPCP) in 1983 (6). Continued development of the process audit has led to a multi-facetted monitoring tool that can provide critical information on plant hydraulic characteristics, process bottlenecks and limitations, and plant performance, as well as energy utilization patterns.

A process audit involves the installation of on-line process monitoring instrumentation which, through a microcomputer data acquisition system interface, allows intensive, short-term monitoring of key process variables within the wastewater treatment facility. The instrumentation includes temporarily installed sensors for dissolved oxygen in aeration tanks, and sensors for suspended solids in the mixed liquor, return sludge and effluent streams and, where available, instrumentation measuring existing plant liquid flow and air flow. The instrumentation is interfaced to a microcomputer for data acquisition and control of instrument multiplexing. Short-term data generated from the on-line instrumentation is analyzed in conjunction with long-term historic data, off-line analytical data, power measurements, and oxygen transfer determinations to define the process capabilities and limitations, as well as the potential for process optimization through automatic process control.

The wastewater treatment plant audit has been applied in mechanical and diffused aeration treatment plants ranging in hydraulic capacity from approximately

4,000 m^3/d to 300,000 m^3/d. Two of these audits are particularly relevant to the subject area of infrastructure rehabilitation because these plants were being considered for expansion. Key findings of these audits are discussed, with attention to their potential impact on the need for expansion at these particular plants.

CAMBRIDGE (HESPELER) WPCP

The Cambridge (Hespeler) WPCP is one of three secondary treatment facilities serving the City of Cambridge in the Regional Municipality of Waterloo.

Plant Description and Problem Definition

The plant is categorized as a high-rate activated sludge plant and has a rated hydraulic capacity of 9,300 m^3/d. A schematic flowsheet of the plant, which incorporates raw sewage lift pumps, manually cleaned bar screens, a comminutor and aerated grit removal tank, parallel aeration tanks each with an integral secondary clarifier, ferric chloride addition for phosphorus precipitation, 2-stage aerobic digestion, and final effluent disinfection with sodium hypochlorite, is shown in Figure 1. The final effluent is discharged to the Speed River.

Based on 1984 estimates of municipal growth prepared by the Region's Department of Planning and Development, the hydraulic capacity of the plant was projected to be adequate to beyond the year 2011. However, the plant has not consistently produced an effluent which meets the MOE guidelines despite operating at only 60% of its rated hydraulic capacity. Therefore, the Region intended to upgrade the plant to provide for improved quality of the discharge. A process audit was conducted at the plant in May, 1986, in order to define the design and operational deficiencies contributing to poor performance, and to develop preliminary design and costing information to upgrade the plant.

Results and Process Audit

A thorough review of historic performance data indicated that the plant was not capable of achieving the MOE guidelines in terms of BOD_5 and suspended solids despite evidence suggesting that a significant amount of nitrification was occurring in the system. These data, summarized in Table 1, provided strong evidence that the principal cause of poor performance was plant hydraulics rather than biological process limitations.

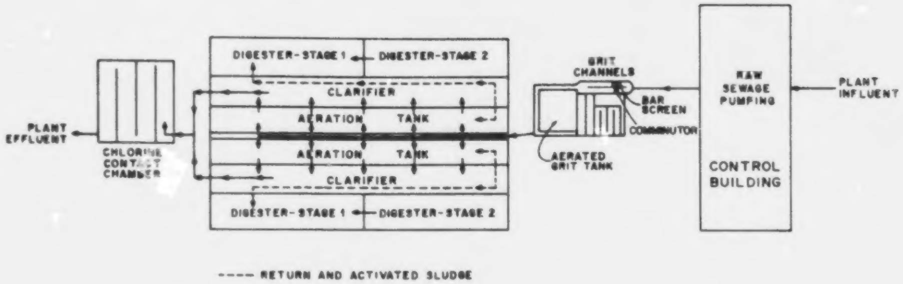
PLANT EFFLUENT
CHLORINE CONTACT CHAMBER
DIGESTER-STAGE 1
DIGESTER-STAGE 2
CLARIFIER
AERATION TANK
AERATION TANK
CLARIFIER
DIGESTER-STAGE 1
DIGESTER-STAGE 2
---- RETURN AND ACTIVATED SLUDGE
GRIT CHANNELS
BAR SCREEN
COMMINUTOR
AERATED GRIT TANK
RAW SEWAGE PUMPING
CONTROL BUILDING
PLANT INFLUENT

Fig. 1 Schematic Flowsheet of Cambridge (Hespeler) WPCP

TABLE 1. Summary of Historic Performance Data (1983-1986)

PARAMETER	AVERAGE	MAXIMUM	DESIGN OR GUIDELINE
Daily Flow (m^3/d)	5,430	11,600	9,300
Peak Flow (m^3/d)	12,400	27,300	-
Influent BOD$_5$ (mg/L)	92	188	220
Influent TSS (mg/L)	114	637	200
Influent TKN (mg/L)	31.0	84.0	-
Effluent BOD$_5$ (mg/L)	30	120	25
Effluent TSS (mg/L)	28	122	25
Effluent TKN (mg/L)	13.2	36.5	-

On-line monitoring data confirmed a high correlation between plant flow and effluent quality in terms of suspended solids concentrations. Figure 2 shows a typical 2-hour period of time for the east and west portions of the plant. Four parallel raw-sewage lift pumps delivered raw sewage to the plant. These pumps were activated by level switches and operated in an on-off mode. The hydraulic disturbances created by the on-off pump cycles, shown for a 24-hour period in Figure 3, caused measurable deterioration in effluent quality which were identifiable by the on-line suspended-solids sensors. The impact was more significant in the west plant than in the east plant despite similar hydraulic loadings.

The aeration/clarification system of the east plant had been modified in 1978 to reduce hydraulic disturbances created by the air lift sludge recycle mechanisms used in the plant. These modifications contributed to the improved performance of the east plant compared to the west plant; however, the online monitoring data identified several other factors which were also responsible for the superior performance of the east plant. Poor air flow distribution within the entire plant was a major factor as serious dissolved oxygen (DO) limitations were identified in the plant despite the underloaded condition of the process.

Air is supplied by three parallel positive displacement blowers through a common header to aeration tanks, aerobic digesters, aerated grit tank, and return sludge air lifts. Significant periods of low DO (<1 mg/L) were identified in both aeration tanks (See Figure 4). These cyclic, low DO periods were correlated to the fill-and-draw operation of the aerobic digesters. The change in liquid level in the digesters during these operations disrupted the plant air flow, diverting excessive amounts of air to the digesters at low liquid levels and excessive amounts of air to

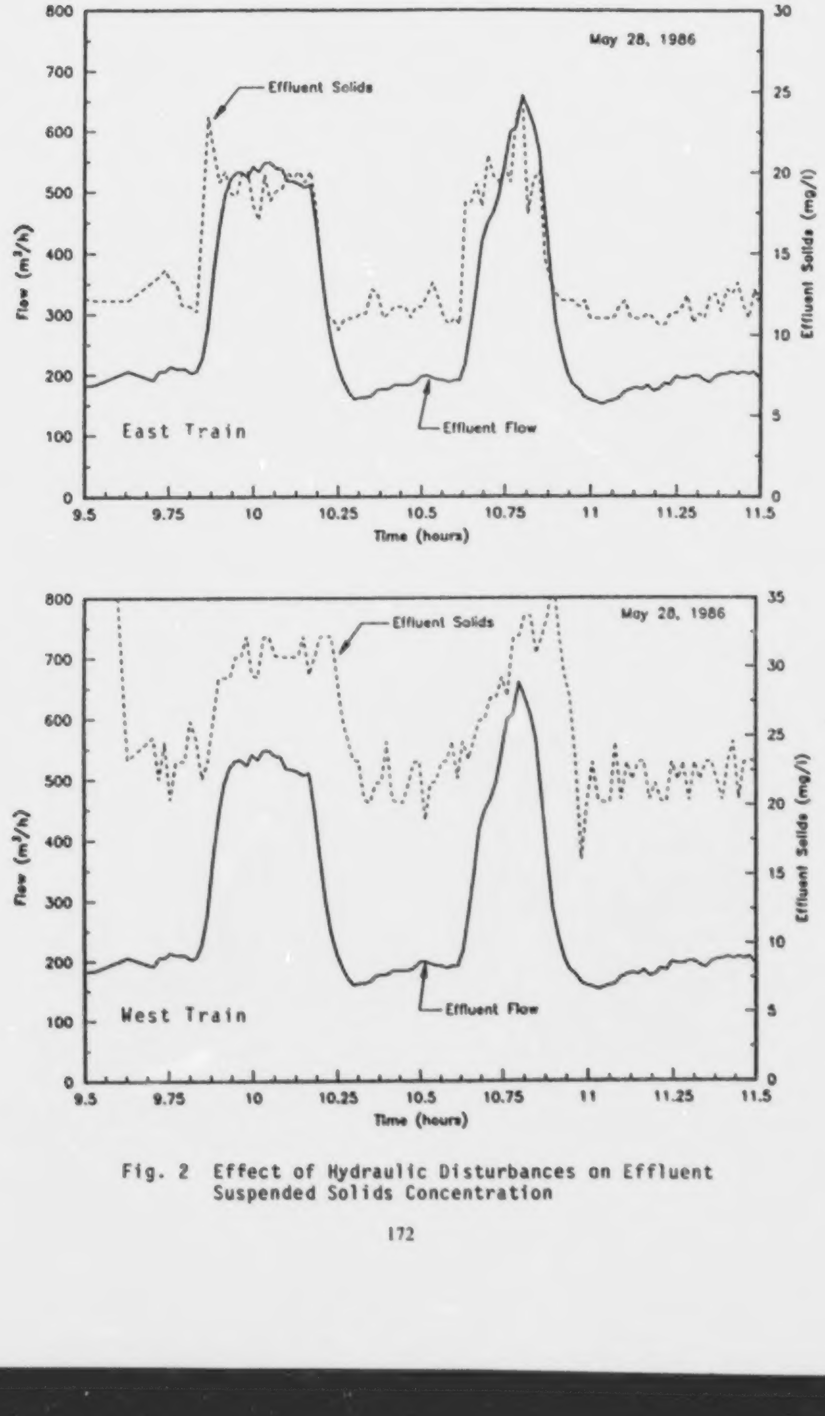

Fig. 2 Effect of Hydraulic Disturbances on Effluent Suspended Solids Concentration

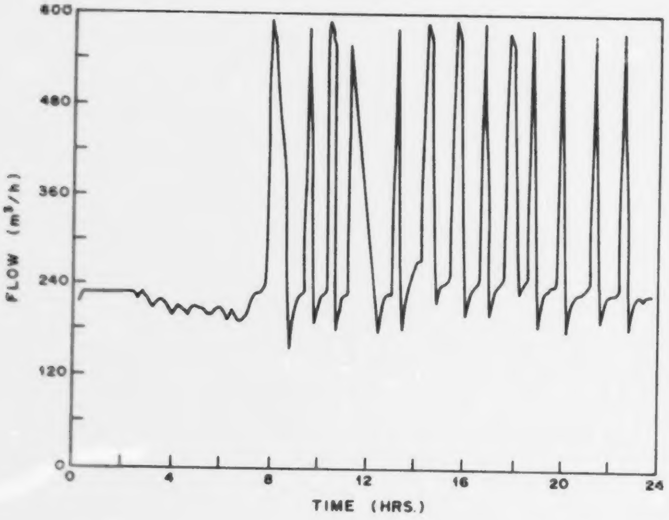

Fig. 3 Dynamic Variations in Raw Sludge Flow

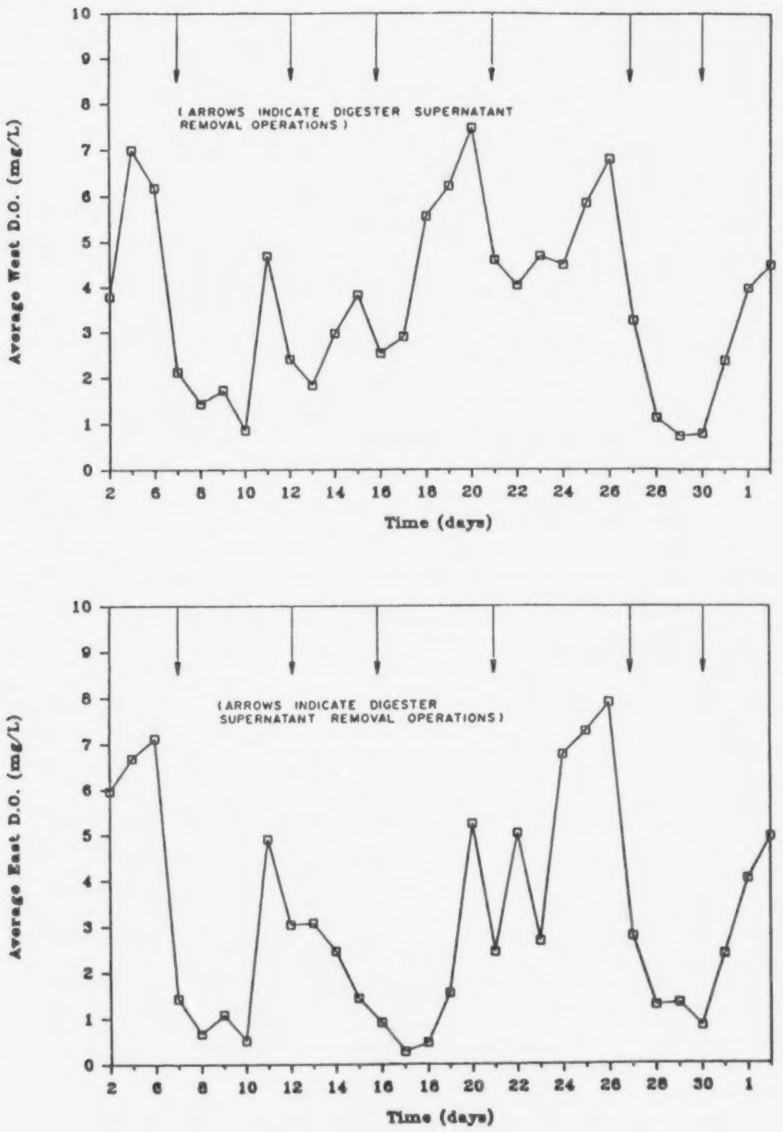

Fig. 4 Effect of Plant Operations on the Daily Average Aeration Tank Dissolved Oxygen

the aeration tanks when the digesters were filled. High air flow to the aeration tanks produced high shear forces on the microbial floc, causing a deterioration in sludge settling properties. Lack of air flow instrumentation, DO monitoring instrumentation and blower output or air distribution control limited the ability of plant staff to adjust the aeration rates within the process.

The west aeration tank received an airflow as much as 100% higher than the east aeration tank because a higher biomass inventory (4,720 mg/L) was maintained in the west portion of the plant than in the east (2,500 mg/L). Therefore, shear forces were higher and secondary clarifier solids loading were higher in the west plant than in the east plant, all of which contributed to the poorer performance of the west plant secondary clarifier.

Recommended Plant Upgrading

As a result of the process audit, three key factors were identified as significant contributors to the poor performance of the Hespeler WPCP:

1) hydraulic disturbances created by the on-off operation of the raw-sewage lift pumps;
2) inadequate control of airflow distribution between aeration tanks and aerobic digesters; and
3) higher mixed liquor suspended solids concentrations in the west plant than in the east plant.

To rectify these deficiencies, modifications to the raw sewage pumping and airflow distribution systems were recommended. Variable-speed pumping capability needed to be provided to eliminate hydraulic disturbances. Separation of the air supply to the digesters and aeration tanks, along with on-line control of the air supply to the aeration tanks, was recommended to eliminate the DO-related process problems. Improved analytical procedures for operators were specified to ensure equal MLSS concentrations in the individual aeration sections.

Major capital work had been anticipated to upgrade plant performance, including the construction of new secondary clarifiers at an estimated cost of $1.7 million. The cost of the proposed short-term corrective measures has been estimated at $500,000. Implementation of these measures is on-going and a follow-up monitoring program is scheduled to evaluate the success of the plant modifications. The extent to which major capital expenditures at the plant can be postponed as a result of the process evaluation will depend on the findings of this post-monitoring period.

KITCHENER WPCP

The Kitchener WPCP is a conventional activated sludge treatment facility which incorporates two separate secondary treatment components constructed in 1962 (Plant 1) and 1974 (Plant 2).

Plant Description and Problem Definition

The plant consists of a common primary section (See Figure 5) which includes three parallel, automatically raked bar screens, two parallel detritors and four parallel primary clarifiers. Plant 1 is a 'plug-flow' aeration system with four circular secondary clarifiers, while Plant 2 is a 'completely-mixed' aeration system with four circular secondary clarifiers. The secondary effluents are combined for chlorination prior to discharge to the Grand River. Rated hydraulic capacity of the existing facility is 122,740 m^3/d.

In 1985, the plant operated at an average daily flow of 64,540 m^3/d or approximately 53% of its rated capacity. Under these conditions, the plant has consistently produced a high quality effluent exceeding the discharge guidelines imposed by the MOE. However, the Grand River Basin Water Management Study (7) recommended that advanced wastewater treatment, including nitrification and effluent filtration, be implemented at the Kitchener WPCP. Proposed abstraction of water from the Grand River has made upgrading of the effluent quality a priority.

To establish the capability of the existing facility and estimate the extent of expansion necessary to achieve the future effluent quality requirements, a process audit was conducted at the plant in March and April, 1986. A major effort during the audit was directed at establishing the oxygenation capacity (O.C.) of the plant aeration hardware because this was considered to be the factor limiting the capability of the plant to maintain nitrification in the future.

Results of Process Audit

Oxygen transfer in Plant 1 is accomplished by 14 shaft-driven mechanical surface aerators in each of the four aeration tanks. Each aeration tank is divided into seven compartments, with two aerators per compartment. The aerators in the first three compartments are driven at a higher rotational speed (40 rpm) than those in the final four compartments (35 rpm). The oxygen transfer capability of this hardware is sensitive to the submergence level of the aerators. Further, the 14 aerators in tank 1 recently had been refurbished, whereas original hardware was in place in tanks 2.

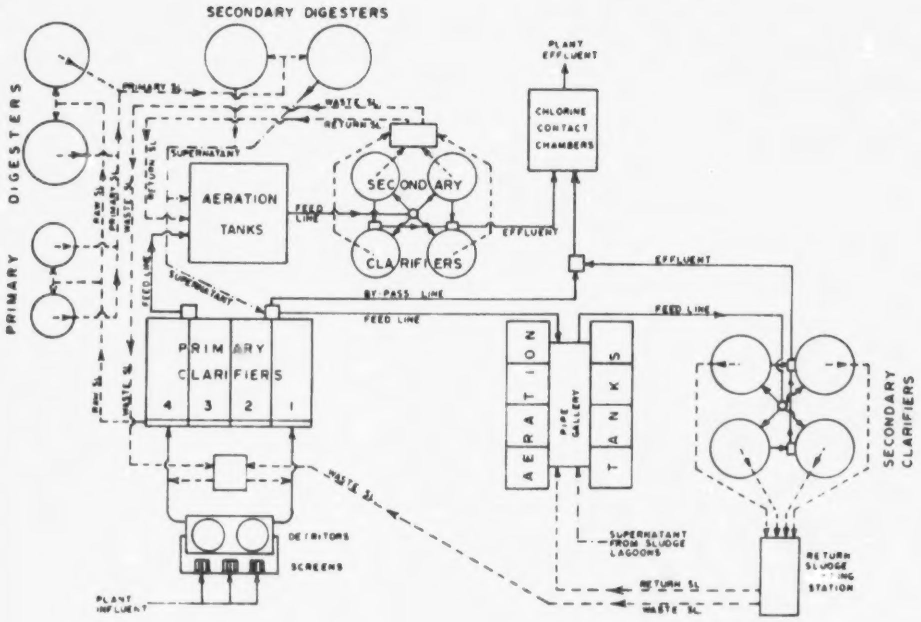
SECONDARY DIGESTERS
PRIMARY DIGESTERS
PRIMARY SL
WASTE SL
RETURN SL
SUPERNATANT
RAW SL
PRIMARY SL
WASTE SL
RETURN SL
AERATION TANKS
FEED LINE
SECONDARY CLARIFIERS
EFFLUENT
PLANT EFFLUENT
CHLORINE CONTACT CHAMBERS
FEED LINE
SUPERNATANT
BY-PASS LINE
FEED LINE
EFFLUENT
FEED LINE
PRIMARY CLARIFIERS
4
3
2
1
RAW SL
WASTE SL
AERATION TANKS
PIPE GALLERY
SECONDARY CLARIFIERS
WASTE SL
DETRITORS
SCREENS
PLANT INFLUENT
SUPERNATANT FROM SLUDGE LAGOONS
RETURN SL
WASTE SL
RETURN SLUDGE
STATION

Fig. 5 Schematic Flowsheet of Kitchener WPCP

Oxygen transfer coefficients (k_La) were measured in each compartment of Tank 1 (refurbished aerators) and Tank 2 (original aerators) at minimum and maximum submergences. The results have been summarized in Table 2.

TABLE 2. Oxygen Transfer Coefficients*

LOCATION			k_La 20° C	
Tank	Compartment	Aerator Speed (rpm)	Minimum Submergence	Maximum Submergence
1	1	40	2.23	3.63
	2	40	1.88	3.45
	3	40	1.74	3.06
	4	35	1.30	2.30
	5	35	1.39	2.02
	6	35	1.30	2.08
	7	35	1.32	1.95
2	1	40	1.55	2.85
	2	40	1.37	2.77
	3	40	1.14	2.22
	4	35	1.00	2.07
	5	35**	0.95	2.04
	6	35	0.89	2.02
	7	35	0.82	1.76

* k_La, 20° C represents the oxygen transfer coefficient at 20° C; units are h^{-1}.

** Average of compartments 4 and 6 due to faulty measurement cell.

The results irdicate that oxygenation capacity could be increased from the present level of 300 kg O_2/h (20° C) to 430 kg/h by refurbishing all aerators, increasing the rotational speed of all aerators to 40 rpm and operating at maximum aerator submergence.

Similar testing was conducted on the aeration hardware in Plant 2 where each of eight completely mixed aeration tanks is equipped with a single 75-kW surface aerator. These tests indicated that maximum oxygen transfer was achieved at approximately 58 kW active power draw, at which point the oxygenation capacity in Plant 2 was approximately 440 kg 0_2/h compared to 250 kg/h under the same conditions but at minimum aerator submergence. It was also found that the efficiency of the newer aerators in Plant 2, at 1.26 kg 0_2/kWh, was significantly lower than that of the older aerators in Plant 1, at 1.59 kg 0_2/kWh.

Overall plant oxygenation requirements were projected, based on growth predictions of the Region's Department of Planning and Development for treatment with and without the nitrification requirement. Nitrification significantly increases the oxygen requirements of the plant compared to conventional treatment (see Figure 6). Based on the results of the oxygen transfer measurements made at the plant, the demand will approach the present transfer capability of the plant by the year 2001. However, the proposed low-capital cost modifications to Plant 1 aeration hardware will provide adequate oxygenation capacity to well beyond the year 2011. Further, low-cost modifications to the aeration hardware in Plant 2 to improve the efficiency to near that of the equipment in Plant 1 would provide an additional margin of safety.

The on-line monitoring also identified significant hydraulic disturbances in the plant. It was found that although the total flow to the plant followed a typical diurnal pattern, the flow oscillated between Plants 1 and 2 with a periodicity of about 60 minutes (see Figure 7). This oscillation resulted from the characteristics cycle of the two operating bar screens. The cleaning of these automatic screens was triggered by independent differential pressure sensors. As one screen was cleaned, all flow tended to be directed through that screen rather than through the other partially clogged screen. This hydraulic imbalance was propagated through the entire plant because no point of flow balancing was available downstream of the screens. Removal of a stop log in the effluent channel downstream of the primary clarifiers eliminated the hydraulic disturbances on the secondary sections of the plant. Figure 8 shows a typical diurnal pattern of total and Plant 1 flow after elimination of the bar screen disturbances on the aeration tanks. Numerous small peaks with a periodicity of about 75 minutes were superimposed on the background flow to the plant. These peaks were characteristic of an on-off lift station near the plant. The peak flow contribution of this pumping station represented about 4% of the peak flow to the plant, amounting to about a 13,000 population equivalent. At existing hydraulic loading conditions, these hydraulic disturbances had not affected plant performance adversely; as the plant approaches design capacity, however, such undesirable hydraulic patterns will have a more significant impact on plant performance.

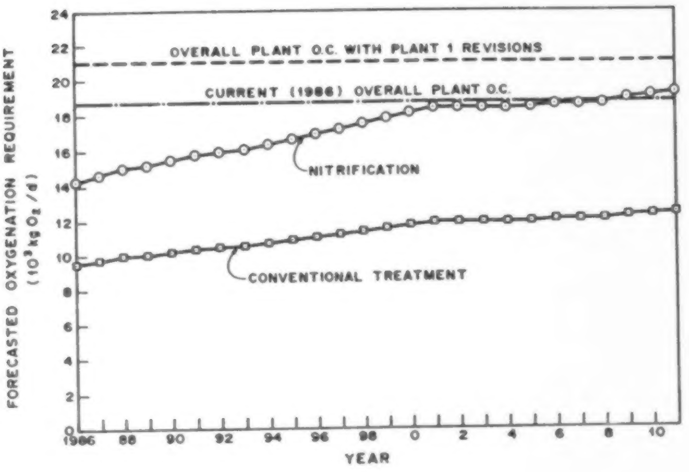

Fig. 6 Oxygenation Requirement for Overall Plant

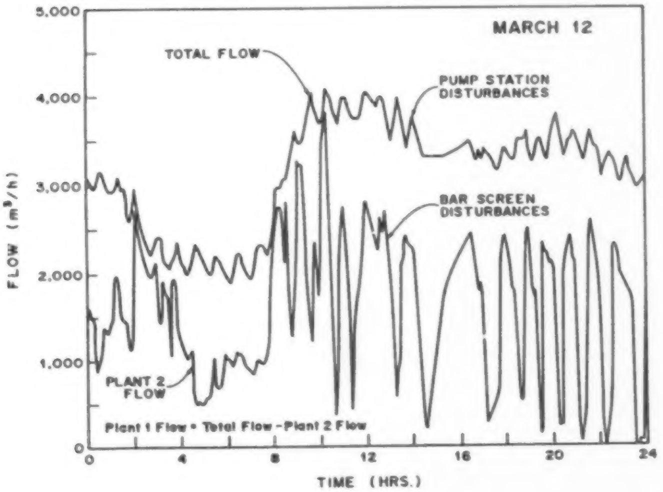

Fig. 7 Flow Variations to Plant Prior to Elimination of
Bar Screen Hydraulic Disturbances

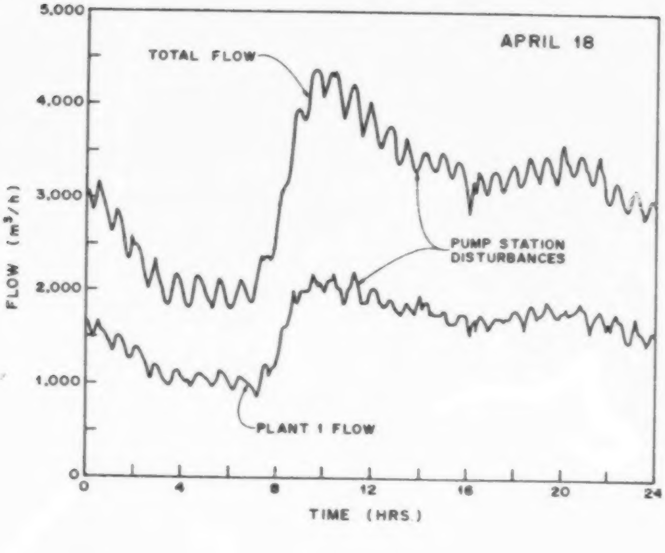

Fig. 8 Flow Variations to Plant After Elmination of Bar Screen Disturbances

Plant Expansion Requirements

The process audit indicated that in terms of oxygen transfer capability, the Kitchener WPCP can meet the demands imposed by a nitrification requirement to beyond the year 2011 with minor upgrading of the Plant 1 aeration hardware. Expansion of the aeration component of the plant, or the addition of a tertiary biological process, at high capital costs to achieve nitrification will not be required according to the results of the plant audit. Furthermore, minor modifications to address the hydraulic disturbances at the plant should improve plant performance as the hydraulic load increases to the design level.

On-line DO instrumentation and control hardware was recommended for the Kitchener WPCP to maximize the efficiency of nitrification in the process by ensuring that DO limitations would not reduce biological activity. Part of the cost of the control hardware will be recovered by the reduced energy use associated with aeration.

MERITS OF WASTEWATER TREATMENT PROCESS AUDITS

The rapidly escalating costs of sewage treatment plant upgrading and expansion makes it imperative that municipalities make maximum use of their existing facilities. Expansion plans must take into account the full capability of the existing hardware. This capability, in some cases, may be significantly greater than the hydraulic rating of the facility because of the conservative design practices which have been used. Further, optimization of the facility, through the use of on-line instrumentation and control techniques, and through the elimination of hydraulic and process bottlenecks, often can reduce the extent and cost of expansion.

Experience has shown that conventional sampling and analysis of a wastewater treatment plant provides inadequate information for judging the dynamic performance of a plant or for designing a control system. The wastewater treatment process audit, using a portable microcomputer-based real-time monitoring system, can be a valuable tool to assist engineering and operations staff in defining the condition of the existing facility. Considerably more information can be acquired with less effort than can be obtained through manual or discrete sampling. Furthermore, dynamic characteristics, such as hydraulic disturbances, oxygen transfer limitations, or biomass inventory imbalances, which may be extremely difficult to identify by conventional methods, are identified readily by the process audit.

The two case histories presented have indicated the value of the process audit in situations where plant refits or expansions are contemplated. With the level of expenditure predicted by the FCM survey to maintain all components of the urban infrastructure, optimization of the existing infrastructure must not be neglected.

ACKNOWLEDGMENTS

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URBAN INFRASTRUCTURE: MUNICIPAL LIABILITY

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ABSTRACT

An investigation of the legal framework affecting municipalities reveals that liability will result under certain circumstances if public urban infrastructure is allowed to deteriorate beyond acceptable levels. The point at which a lack of care will result in liability depends on a number of criteria, including whether liability is based on a municipality breach of a statutory duty to repair or maintain, or upon negligence of the municipality in the operation of its services that results in damage to property or individuals. These matters are considered in the context of the municipality's responsibility to repair and maintain its roads, sidewalks, bridges, buildings, and underground piping systems. In addition, the manner in which the need to meet increasingly more stringent environmental legislation may result in the maintenance or renewal of some feature of the municipal infrastructure is considered.

RÉSUMÉ

L'examen des dispositions légales touchant les municipalités démontre qu'une part de la responsabilité incombe à ces dernières lorsqu'elle laissent l'infrastructure urbaine se détériorer au-delà d'un certain point.

Le moment à partir duquel le manque de soin entraîne une responsabilité d épend de divers critères: la responsabilité de la municipalité peut être définie en fonction d'un manquement à son devoir statutaire de réparer ou d'entretenir l'infrastructure; elle peut également être fonction de la négligence dont la municipalité a fait preuve dans l'exploitation de ses services, négligence qui a occassionné des blessures à des particuliers ou l'endommagement de leurs biens.

L'auteur examine ces questions dans le contexte de la responsabilité de la municipalité de réparer et d'entretenir ses routes, trottoirs, ponts, immeubles et réseaux de canalisations souterraines. Il examine également la façon dont

l'obligation de satisfaire aux exigences d'une législation de plus en plus stricte en ce qui concerne l'environnement peut forcer à entretenir ou renouveler certains éléments de l'infrastructure municipale.

INTRODUCTION

Municipalities in Ontario have taken on -- or been given -- administrative functions for a broad range of activities respecting local government services. In this regard, a municipality is primarily responsible for providing such urban infrastructure as roads and bridges, as well as underground water and sewage piping systems. As these systems deteriorate, the municipality experiences increasing costs for repairs. Faced with this prospect, municipal governments must determine a maintenance strategy for the preservation of various parts of the infrastructure. Assuming that the municipality does not have unlimited resources to maintain its infrastructure at an ideal level of repair, the municipality must decide what level of maintenance is acceptable.

To determine an appropriate level of repair, the municipality must consider the practical limits of its administrative, budgetary, and political environments. In addition to these matters, the municipality must also consider the legal consequences of adopting a level of repair which may not meet the legal standard of care applicable to each of its public works. A breach of an established standard of care could result in the municipality's incurring the increased cost of defending court actions and bearing damages or higher costs of insurance, or both, as people are harmed or properties damaged. These can be described as the hidden (and often uncounted) costs of failing to maintain municipal infrastructure. Ultimately, the legal liability to be imposed on a municipality may affect its flexibility in determining the extent of repairs or maintenance it is prepared to undertake.

BASIS OF LIABILITY

Nature of a Municipal Corporation

The municipal corporation is much like any other corporate entity in that it possesses certain rights, powers, and duties which defines it as a legal unit distinct from its composite members. Unlike private corporations, the municipal corporation came into existence exclusively through provincial legislation.

As a statutory corporation, a municipality is vested with the authority to carry out many activities under the Municipal Act [R.S.O. 1980, c. 302] and other provincial legislation. These statutes either give the municipality the discretion to carry on an activity, or instruct the municipality to carry out an activity. In the first instance, the statute gives the municipality a power to conduct an activity if it so chooses. In the second instance, the municipality is under a statutory duty to conduct the activity. This distinction affects the nature and the extent of the municipality's liability for the non-repair in the context of its public urban infrastructure. [Anns and others v. London Borough of Merton (1971) 2 All E.R. 492; Kamloops v. Nielson (1984) 26 M.P.L.R. 81 (S.C.C.); Barratt v. North Vancouver (1980) 2 S.C.R. 418; 27 B.C.L.R. 182 (S.C.C.)]

Municipality Liability for Operational Negligence

Generally, a municipality is not liable where it exercises discretionary powers under provincial legislation unless it does so negligently. There is no liability if a municipality chooses not to exercise a discretionary power, but if the municipality chooses to exercise the power it is under an obligation to do so with care. If a municipality fails to act with care, then it may be sued for torts committed by it and is liable for damages. This is known as operational negligence and involves the careless acts of the municipality or its employees in implementing a policy instituted pursuant to an exercise of the municipality's discretion.

If municipality has the power to provide a public work and to conduct maintenance and repairs on that public work, in the event of injury to property or persons, the Court considers whether or not the municipality has failed to take proper care in the implementation of its chosen maintenance program. It will not consider whether the municipality has an effective policy with regard to the maintenance of its infrastructure. This allows a municipality to determine whether or not repairs will be conducted and, if undertaken, what level of repair it will adopt. Only if the municipality fails to maintain its own policy standards does liability for operational negligence result.

Municipal Liability for Breach of a Statutory Duty

Alternatively, if the municipality has a statutory duty to act in a certain manner, it will risk liability for failure to act as prescribed by the statute. Generally, if the duty is not discharged under the terms of the statute, liability will result. This places the municipality in an unique position because it may be liable for the exercise or non-exercise of municipal duties where no action exists at common law. The nature and extent of the liability to be imposed depends on the express or implied terms of the statute. As a result, not every duty results in the same level of liability for its non-performance, however, the existence of a duty imposing liability usually gives a broader range of remedies to the injured party, including the right to require that the duty be performed.

If the municipality is compelled to act by a court order, it cannot avoid the costs of repair by choosing not to act or to reduce costs by establishing its own maintenance program without regard to the legislated standards.

URBAN TRANSPORTATION INFRASTRUCTURE

The extensive network of roads and bridges which make up a large part of urban infrastructure have a relatively short life-span in a harsh, northern environment. The extent to which the municipality is obligated to maintain its transportation infrastructure will have a direct impact on the resources expended for that infrastructure's repair and the freedom of the municipality to control these expenditures. No consideration has been given to the effect of various statutes creating regional, metropolitan or district two-tier municipal structures in the distribution of municipal responsibility as between the levels of government.

Duty to Repair Highways (Municipal Act)

In Ontario, as in most provinces, the municipality is obliged to repair highways and bridges within its jurisdiction. Section 284(1) of the Municipal Act provides:

> s. 284(1) Every highway and every bridge shall be kept in repair by the corporation the council of which has jurisdiction over it or upon which the duty of repairing it is imposed by this Act and, in case of default, the corporation, subject to the Negligence Act, is liable for all damages sustained by any person by reason of such default.

A highway includes virtually any road surveyed or in existence [Municipal Act, R.S.O. 1980, c. 302 s. 257, s.l, para 9] and the municipality generally has jurisdiction over the highways within its territorial boundaries. [Municipal Act, R.S.O. 1980, c. 302 s. 259] The duty to repair highways also encompasses other elements of the urban transportation infrastructure which are proximate to the highway. If, for example, the municipality chooses to construct sidewalks, then the municipality is obligated to keep them in a state of repair that enables people to use them safely. [Green v. Dixon Road Carwash (1981), 33 O.R. 2d 353 (H.C.).] In addition to sidewalks, any wall, fence, guardrail, railing, barrier, or other material or object within the travelled portion of the highway must be kept in a state of repair. [Municipal Act, R.S.O. 1980, c. 302 s. 284(3)] The Courts have also held that the duty includes the erection of boulevards, traffic lights, and signs. [Cook v. Bergevin et al., Ber#evin et al. v. Cook et al. (1977), 2 M.P.L.R. 273; Dubois v. City of Sault Ste. Marie [1971] 1 O.R. 462]

Whether or not a highway is in an adequate state of repair depends upon the interpretation given to the Municipal Act by the Courts. Unfortunately, the Municipal Act itself provides little assistance regarding the standard of care required. On the other hand, the Courts have contributed a considerable amount of jurisprudence to the subject.

No one standard appears to be used but, generally, the duty of repair requires a municipality to use all reasonable efforts to keep its roads (and the other matters described above) in a state reasonably sufficient for the requirements of the traffic using them; that is, in such a condition that a traveller using them in the ordinary way and with ordinary care may do so with safety. [Rogers, Municipal Corporations, Vo1.2, p.1240.]

Admittedly, in any specific situation, general statements of this kind are of little assistance. Whether or not a highway is in an adequate state of repair is a factual matter to be determined case by case. [Weston v. Middlesex (1914) 31 O.L.R. 148, 19 D.L.R. 646 (C.A.); Groves v. County of Wentworth [1939# O.R. 138 at 145 (C.A.).] In order to determine the appropriate standard, many Courts have been assisted by the approach taken in the case of Foley v. East Flamborough [29 O.R. 139 at 141] The Court in Foley determined that the state of repair of any highway is relative to the nature of the locality in which it is found, the financial means available to the municipality obliged to repair the road, and the requirements of the public making use of it.

Following the approach in Foley, a standard is determined with regard to the nature of the locality, be it urban or rural, its relative wealth and the nature of the road itself. For example, a well-travelled thoroughfare in a major city would indicate a higher standard than a country lane winding through a sparsely populated, small agricultural community. As a result, the municipality's liability for the non-repair of its roads in any particular instance is not well-defined. Only a careful survey of cases involving the duty to repair in comparable circumstances will assist a municipality in establishing repair and maintenance programs or revising existing programs.

Duty to Repair Bridges (Municipal Act)

Even though the statutory provision creating a duty to repair highways includes bridges, the standards of care applied are not similar. [Municipal Act R.S.O. 1980, c.302, s.284(1)] If a municipality chooses to construct a bridge, or has been given jurisdiction over an existing bridge, it is obligated to ensure that the bridge maintains a reasonable standard of strength with regard to its ordinary use by the public. [Scofield v. Oakville [1968] 2 O.R. 490 (Ont. C.A.).] The duty has been narrowed to the extent that no liability will result from inadequate guardrails on the sides of the structure. [Municipal Act R.S.O. 1980, c.302, s. 284(3); Hopper v. Bruce [1950] O.R. 284 (C.A.).] Thus it would appear that if the bridge does not give way, then the municipality has discharged its responsibility for maintenance. In this regard, a municipality should have a program to ensure the strength of the bridges within its jurisdiction.

Liability for Non-Repair of Highways and Bridges (Municipal Act)

The case of Vancouver v. Cummings [(1912), 46 S.C.R. 457, 2 W.W.R. 66, 2 D.L.R. 253] established that liability for non-repair of highways and bridges is founded on the duty to repair independent of any negligence. The duty is absolute to the extent that no advance notice need be given to the municipality of the defect causing the damage. If damage occurs as a result of a road being in need of repair, this is enough to establish a prima facie case against the municipality.

To avoid liability, the municipality must establish that it made all reasonable efforts to repair the defect. [Dubois v. City of Sault Ste. Marie [1971] 1 O.R. 462 at 465.] If the municipality fails to do so, then the following remedies are available to someone harmed.

First, as noted previously, the Municipal Act [R.S.O. 1980, c.302, s.284] establishes the municipality's obligation to financially compensate an injured party subject to the provisions of the Negligence Act [R.S.O. 1980, c.315].

Second, a breach of the duty to repair is at common law, under the Municipal Act of 1859, and under the Criminal Code, an indictable offence making the municipality liable to a fine. [Rogers, Municipal Corporation, Vol. 2, p. 938] The rules that must be followed to achieve success in this regard are highly formalistic in that the Attorney General of Ontario must permit a prosecution which makes the process inconvenient and to a large extent inaccessible; however, it remains a possible remedy.

Third, a Court may be asked to issue an order that requires the municipality to undertake repairs. It must be emphasized that the ability to ask for the Court's interference in the municipality's affairs where a duty is created by a statute is much greater than where the municipality is negligent in the exercise of a discretionary power. Consequently, the effect on a municipality of a breach of the duty to repair highways and bridges is potentially much greater than for negligence in the exercise of a discretionary power, and the municipality must consider the level of maintenance necessary to avoid these costs.

UNDERGROUND PIPING SYSTEMS

Every municipality is involved in the supply of drinking water, sewage disposal, drainage and flood control services to its residents. These services involve an elaborate network of public works including an extensive system of piping usually located beneath municipal streets. The municipality's obligations with respect to the repair of drainage, sewage and water works are discussed below. The distribution of municipal responsibility between regional, metropolitan, and district two-tier municipal structures is not being considered in the following discussions.

Drainage Works

A municipality has the power under the Municipal Act [R.S.O. 1980, c.302, s. 208 para 13] and the Drainage Act [R.S.O. 1980, c.126] to construct drainage works to remove surface water and prevent flooding. The obligation to repair differs depending on whether or not the particular drainage works are constructed under the authority of the Municipal Act or the Drainage Act.

Negligent Operation of Drainage Works (Municipal Act). The Municipal Act authorizes the municipality, at its discretion, to undertake the maintenance, repair, and improvement of drains within its territory. [R.S.O. 1980, c. 302, s. 208 para 13] There is no related duty to maintain and repair if the municipality chooses to construct drainage works. As a matter of good sense most municipalities undertake maintenance and repairs of its drains and by doing so will be required to implement this maintenance policy without negligence.

The following is an example of how this responsibility works. A tree's roots were blocking a drain. In similar situations, the municipality usually cut down the tree to relieve the blockage and prevent further problems. In this case, the municipality failed to cut down the tree after being notified of the problem. Damage was suffered. The municipality was found to be negligent in the implementation of its own standard of repair and liable in damages for the loss caused. [Buie et al. v. Borough of Etobicoke et al. (1978) 25 M.P.L.R. 70]

Duty to Repair Drainage Works (Drainage Act). The Drainage Act also authorizes the municipality to construct certain drainage works under a defined system of financing. Under this statute, drainage works include any drain, the improving of natural watercourses and works necessary to regulate water table or other water levels on any property whether this involves a dam, embankment, wall, or other protective works. [R.S.O. 1980, c. 126, s.1 para 1]

Even though a municipality is not compelled to undertake drainage works under the provisions of the Drainage Act, if any drainage work is undertaken pursuant to its provisions, there is a duty to repair and maintain them. [R.S.O. 1980, c. 126, s. 74] In this regard, section 74 of the Drainage Act provides:

> Any drainage works constructed under a by-law passed under this Act or any predecessor of this Act, relating to the construction or improvement of a drainage works by local assessment, shall be maintained and repaired by each municipality through which it passes...

The standard of repair required by the Drainage Act is clearly defined in the definitions of "repair" and "maintenance" found in the statute. These definitions indicate that a municipality should do whatever is necessary to put the drainage work in a proper condition to carry off the water flowing into it with regard to the purposes for which it was constructed [Peltier v. Dover East (1897) 1 C & S 323] The municipality must maintain drainage works in a condition sufficient to carry the level of water flow originally intended at the time of construction. This requires that pipes be kept clear of obstructions, that any pumping machinery be kept in repair [Bradley v. Raleigh (1905) 10 O.L.R. 201], and that bridges or culverts essential for the operation of the drainage work also be kept in repair [Camden v. Dresden (1903) 2 O.W.N. 200]. The municipality's responsibility is reduced to the extent that the Drainage Act requires property owners to clear drains of any obstructions for which they are responsible. [R.S.O. 1980, c. 126, s. 80] Any other necessary repairs are the responsibility of the municipality.

Liability for Non-Repair of Drainage Works (Drainage Act). Unlike the duty to repair highways, the duty to repair drainage works constructed under the Drainage Act is not absolute. The Drainage Act requires notice of the need for repair to be given to the clerk of the municipality before liability for damage caused by non-repair is triggered. [R.S.O. 1980, c. 126, s. 79(2)] . If the notice required under section 79(1) of the Drainage Act is given, any damage through the negligence of the municipality is recoverable in damages. [Re Eek and King [1970] 2 O.R. 700]. It is clear that if a municipality does not act expeditiously to remedy a situation after it has been given notice, it risks liability to anyone affected by the lack of repair.

In addition to the remedy for damages, the Drainage Act permits anyone affected by the lack of repair to seek an order from a referee, nominated under the Drainage Act, to compel the municipality to repair the drainage work if the municipality has not undertaken the repair within 45 days after the notice of the problem. [R.S.O. 1980, c. 126, s. 79(1)] This process might result in a requirement that the municipality undertake the repairs necessary to relieve the drainage problem.

It allows an injured party to remedy flooding in addition to recovering monetary damages for the creation of the nuisance caused by lack of drainage from his property.

Sewage Works

The authority to construct, repair, maintain, and improve sewage works for the removal and treatment of liquid waste within the municipality is found under both the Municipal Act [R.S.O. 1980, c. 302, s. 210 para 78] and the Local Improvement Act [R.S.O. 1980, c. 250]. The scope of the power under the Municipal Act usually extends to the whole municipal sewage system; whereas a sewage work constructed as a local improvement is usually undertaken in limited areas of the municipality. Also, the liability of the municipality to repair a sewage work under the two statutes is substantially different.

Negligence in the Repair of Sewage Works (Municipal Act). Sewage works completed under the authority of the Municipal Act [R.S.O. 1980, c. 302, s. 210, para 78] include sewers, pumping stations, treatment plants and any other works necessary for the operation of a sewage system. As a general rule, the municipality is not under any duty to repair its sewage system; however, the same basic principles concerning the failure of a municipality to conform to its own voluntarily established standard of care (and repair) discussed previously in the context of drainage works constructed under the Municipal Act apply here. Furthermore, a municipality is obliged to supply sewage service from an existing system to all that apply for it. [A.G. Can v. Toronto (1893) 23 S.C.R. 514; Cornwall v. St. Lawrence Rendering Co. [1951] OR 669; Herman Bros. Ltd. v. Regina (City), [1987] 4 M.P.L.R. 233 (Sask .C.A.)] Thus, it seems that to the extent that a municipality undertakes to operate a sewage system, it must ensure that it maintains that level of service to its inhabitants and, thus, the municipality comes under an indirect duty to repair and maintain its system.

Duty to Repair Sewage Works (Local Improvement Act). If a municipality has constructed parts of its sewage network under the provisions of the Local Improvement Act [R.S.O. 1980, c. 250], the municipality is required to repair these works. Section 60(1) of the Local Improvement Act provides:

> When a work has been completed, it shall be kept in repair and maintained and may be renewed or replaced at the expense of the corporation and the corporation may by by-law provide for the issue of debentures for such renewal or replacement.

Like the duty to maintain drainage works constituted under the Drainage Act, the sewage works constructed under the Local Improvement Act must be kept at a level of repair that allows the system to operate at its designed capacity. This entails the repair of equipment and the cleaning and replacement of pipes to meet its obligation. The mere presence of a state of non-repair is not enough to support an action against the municipality. The municipality must be notified of the problem or not take reasonable care to acquire knowledge of the problem. If notice is given or knowledge is obtained of a need for repair, any lack of care in remedying the problem is negligence and will result in liability. [Crosty v. City of Burlington et al. (1978), 21 O.R. (2d) 753]

Liability for Non-Repair of Sewage Works (Local Improvement Act). If the municipality is liable, then an injured party may apply for damages, for an order compelling the municipality to conduct the necessary repairs, or for both under section 61(1) of the Local Improvement Act. The Local Improvement Act also gives the judge the discretion to determine what repairs are necessary and direct them to be carried out under proper supervision. [R.S.O. 1980, c. 250, s. 61(2) and (3)]

Effect on Existing Sewage Works (Ontario Water Resources Act). Whether the sewage work was undertaken by authority of the Municipal Act or the Local Improvement Act, the municipality may be required to enact the necessary by-laws for the extension, alteration, or replacement of the existing works by the Ontario Water Resources Act [R.S.O. 1980, c. 361 s. 32(1)]. Furthermore, if a Director, appointed pursuant to this Act, determines that the deterioration of a sewage system may result in sewage backup or a decrease in treatment efficiency, he may order the needed repairs [R.S.O. 1980, c. 361,s. 33] This will depend on the possible effects of the deterioration on the environment and whether it poses a danger to the public's health. If the Director so orders, it becomes the statutory duty of the municipality to commence and complete the needed work. [Ontario Water Resources Act R.S.O. 1980, c. 361, s. 33(1)] If the municipality does not comply, it is liable to fines of up to $500 per day. As a result, the municipality can be compelled to improve, alter, or repair its sewage system to protect the public's health.

Water Supply System

The supply of drinking water is a "public utility" governed by the Public Utilities Act [R.S.O. 1980, c. 423]. This Act governs the supply of water, artificial or natural gas, electrical power or energy, and steam or hot water [R.S.O. 1980, c. 423, s. 1 and s. 17] by municipalities whether they operate them directly or through publicly owned utility commissions. The Public Utilities Act specifically empowers the municipality to acquire, establish, and operate water works for the supply of drinking water to its inhabitants. The power is generally a permissive one, but most municipalities have undertaken to supply this public utility.

Duty to Supply Water (Public Utilities Act). If a municipality establishes a water supply system, it is required to supply the utility to all buildings and lands along the lines of supply within the municipality upon the request of the owner. [Public Utilities Act, R.S.O. 1980, c. 423, s. 54] The municipality may only discontinue service for lack of payment or a breach of the regulations or the Act. If the service is interrupted for any other reason, the owner affected may apply to a Court of competent jurisdiction for an order compelling the municipality to resume supply. Consequently, the municipality may not allow the utility to lapse into such a state that it could cause the interruption of service to its inhabitants. If interruption occurs, the affected property owners may take action to recover any damage caused by the lapse of service.

Common Law Duty to Supply Pure Water. Municipalities also are obligated to supply a "wholesome and pure supply of water to the consumer". [Munshaw Colour Service Ltd. v. Vancouver (1956), 22 D.L.R. (2d) 197, rev. on other grounds 29 D.L.R. (2d) 240; aff'd [1962] S.C.R. 433] If a municipality fails to provide a safe supply of drinking water, the municipality is answerable in damages. [Dom Canners Ltd. v. Costanga [1923# S.C.R. 46 at 47]

Effect on Existing Water Supply Systems (Ontario Water Resources Act). A municipality may be required to improve or repair its water supply system to conform to the requirements of a Director appointed pursuant to the Ontario Water Resources Act [R.S.O. 1980, c. 361, s. 23(7)]. A report from the Director makes it compulsory that the municipality undertake any necessary work; otherwise the municipality faces fines. As a consequence, a lack of maintenance resulting in the reduction of water quality can result in both the risk of liability and the possible interference of the Director. Therefore, each municipality should establish a level of maintenance and repair consistent with the need to provide for adequate water quality.

BUILDINGS AND OTHER PROPERTY

Municipal buildings generally, and other property occupied by equipment to provide the various municipal services discussed previously, are also part of public urban infrastructure. These include administrative buildings, parking facilities, pumping and transformer stations, recreational and park facilities to name but a few. The use of these facilities varies with their character. The ability of the municipality to limit access to some reduces the possibility of harm, but the public nature of most buildings represents a significant risk of liability if lack of repair results in an unreasonable hazards being present.

Negligence in the Maintenance of Municipal Property (Occupiers Liability Act). The law respecting the liability of municipalities for the non-repair of its property is identical to that of any other person who owns or occupies property. A recent case deals with a municipality's obligation to persons injured while on its property. [McErlean v. Sorel et al. 32 C.C.L.T. 199] The case involved the liability of the City of Brampton for injuries resulting from the collision of two trail bike riders in an abandoned gravel pit owned by the City. The Court determined that the City was negligent in not fencing or posting the site after it gained knowledge of trail bikers using the property and the dangers related to this activity. As a result, the Court placed 75% of the responsibility on the City representing several million dollars. This case is presently under appeal because since the time of the injury in this case, the Occupiers Liability Act [R.S.O. 1980, c.322] has been passed in Ontario. The Occupiers Liability Act [R.S.O. 1980, c. 322] establishes the standard of care owed by occupiers of property to others entering their premises. Section 3 of the Act provides:

> An occupier of premises owes a duty to take care as in all the circumstances of the case is reasonable to see that persons entering the premises and the property brought on the premises by those persons are reasonably safe while on the premises.

and

> The duty of care provided for in subsection (1) applies whether the danger is caused by the condition of the premises or by an activity carried on in the premises.

Unlike the standards applicable in the Brampton case (because the injury occurred before the enactment of the new statute), the Occupiers Liability Act limits liability by requiring the municipality to do only what is reasonable in the circumstances. Also the municipality may escape liability if those entering the premises have accepted the risk of certain harms. [Occupiers Liability Act R.S.O. 1980, c. 322, s. 4(1)] For example, a person may enter premises knowing of certain risks to his safety but enter notwithstanding their presence [Christie v. Toronto (1980), 20 M.P.L.R. 146] or enter restricted premises. This may relieve the municipality of responsibility. [Occupier's Liability Act R.S.O. 1980, c. 322, s. 4(3) and (4)] As a result, the outcome of the Brampton case may be different if conducted under the Occupier's Liability Act.

EFFECT OF ENVIRONMENTAL LEGISLATION ON THE RENEWAL OF URBAN INFRASTRUCTURE

Enhanced public sensitivity to the degradation of the natural environment by inefficient or ineffective sewage treatment plants or by erroneously or poorly constructed storm or sanitary sewers has resulted in an awareness by municipal officials of the need to take corrective action to resolve these environmental concerns. The possibility of prosecution by the Ministry of the Environment for unlawful discharge to the environment from such sources under the Ontario Water Resources Act [R.S.O. 1980, c. 361, s.14] or the Environmental Protection Act [R.S.O. 1986, c. 141, s.16] only increases municipal concerns in this regard.

The indirect result may well be the rebuilding or repairing of significant parts of public urban infrastructure.

CONCLUSION

After a survey of the law relating to the repair of the transportation infrastructure, underground piping systems and buildings under the control of the municipality, it is clear that certain liability will result from the non-repair of these parts of the urban infrastructure. The nature and extent of the liability in any particular case depends on whether or not there is an obligation to repair and, if obligated to repair, what standard of repair is required; or in the absence of a duty to repair, liability may also arise if the municipality does not observe its own policy standards set for the maintenance of an activity.

Regardless of the standards which apply in any circumstance, the municipality must ensure they are maintained in order to escape liability. The municipality must consider how to manage its infrastracture effectively and efficiently to avoid the legal consequences of deterioration. The challenge to engineers, planners, and other administrative personnel is to meet these goals.

THE FEDERAL ROLE IN MUNICIPAL WATER INFRASTRUCTURE

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ABSTRACT

To rehabilitate urban infrastructure does not require the restoration of previously dismantled federal government funding programs to municipalities. What is needed is a more realistic approach toward a water policy by all levels of government. Such a water policy must address the fundamental problem of overuse and abuse of water. That means that Canadians would pay for the clean water supplied to them, and pay according to a rationalized pricing system that would discourage high-volume water consumption. Therefore, to obtain the funding for the renewal of urban infrastructure in Canada requires the political will to ask specifically their users to pay, not the taxpayers generally.

RÉSUMÉ

Il n'est pas nécessaire de rétablir les programmes fédéraux d'aide aux municipalités pour réaménager les infrastructures urbaines. Ce qu'il faut plutôt, c'est que tous les ordres de gouvernement adoptent une attitude plus réaliste face à l'établissement d'une politique des eaux. Celle-ci doit apporter une solution au problème fondamental des emplois excessifs et inappropriés de l'eau: les Canadiens devraient payer l'eau propre qu'on leur fournit, en fonction d'un barème rationalisé de façon à décourager sa consommation en grande quantité. C'est donc dire que, pour rassembler les fonds nécessaires au renouvellement des infrastructures, il faut avoir la volonté politique de demander aux utilisateurs, non pas aux contribuables en général, d'assumer les frais de l'eau consommée.

THE FEDERAL ROLE

The federal government does not intend to restore funding of previously dismantled municipal programs. However, the federal government can work with municipalities more effectively than it ever hasdone before in this vital area. Vital, indeed, because if all three levels of government in Canada do not collectively deal with the growing water problem in the country, the problem will become unmanageable.

Across Canada, municipalities are already struggling with aging plants and delivery systems that undermine the clean water all Canadians need and have a right to expect. But the simpler it is to define the problem, the more elusive workable and affordable solutions are. Indeed, the issue has not been simple since the first water supply systems were built in Canada in the mid-19th Century. Even most of our so-called modern waterworks date back to the end of World War II, and sewer pipes were constructed mainly in the mid-1950s. The total system is outmoded and approaching the end of its lifespan.

What is worse, many communities, including heavily populated ones, are without wastewater treatment. Raw sewage is simply dumped into local waterways. Despite being one of the wealthiest and most modern countries in the world, Canada often manages its water resources with methods that hark back to the 5th Century B.C.

The question is not whether we can do better. Nor is it whether we should. The question is how to pay the bill. Building and maintaining a water infrastructure is, by definition, expensive. Municipalities have always found it difficult to increase taxes. That was even the case in the 1960s, when spending public money was raised to an art form. Now, in the 1980s, municipal politicians think it is almost impossible to make further demands on ratepayers. In their mind, it is hardest of all to do so for a water infrastructure, because, unlike services such as day care or schools, infrastructure is literally underground: not only out of sight, but also out of mind and, therefore, out of fashion. Nobody was ever re-elected by promising better plumbing.

The problem might be marginally more manageable if there were one villain at whose door the rest of us could lay the blame. The fact is that all levels of government represent the bad guy in the sense that each level bears responsibility for deficiencies in treating and delivering safe, clean water to Canadians. With a few shining exceptions, the history of water in Canada is a litany of policies, or the absence of policies, that have made water our most over-used and abused natural resource. Lacking a genuine strategy to manage water wisely, municipalities are under increasing pressure to find a quick fix federal funding. Because basic questions are not even being asked, they are not being answered.

Starting today, a basically different and more realistic approach to a water policy should be taken at all levels of government. We have to admit that the solutions of the past subsidies, a pre-occupation with supply and a blind eye to controlling demand, have solved nothing. In fact, they have compounded the problem. The hard reality is that we have never addressed the root causes of the emerging infrastructure crisis, much less have we taken the tough measures needed to deal with it. But, unless we are prepared to ask the right questions, we cannot provide the right answers. The evidence of failure faces us across Canada.

Fact: Only 10% of all raw sewage east of Ontario is treated.

Fact: More than 8 million Canadians, a third of the entire population, live in municipalities that do not provide sewage treatment.

Fact: Water quality in Toronto, Canada's largest city, is causing so much concern that some politicians are calling for a $200 million pipeline from the Georgian Bay to serve the city.

Fact: Water quality has become such a concern to Canadians that they spent $80 million on bottled drinking water in 1986. The figure is expected to increase by 15% this year.

Fact: The value of our water treatment and delivery systems now totals a staggering $100 billion. The bill for the next 5 years for repairing aging underground pipes alone has been estimated at $3 billion, with an additional $3 billion needed to improve water and sewage treatment facilities. No level of government in Canada is budgeting for rehabilitation programs of that magnitude.

Today, most municipalities in the country are making demands on the federal government for financial support in this area. But these requests ignore the fact that, when the federal government used to fund municipal water infrastructure, the provinces expected to take Ottawa's cash, while refusing to give it any say in how the money was to be spent. The argument was that municipal infrastructure is under provincial jurisdiction. The provinces wanted it both ways: Federal cash and total provincial control, with the federal government relegated to the role of indulgent uncle. The government, not surprisingly, decided to be neither indulgent nor avuncular. It simply abandoned the field, and the federal government hasn't occupied it since.

The calls for money continue, despite the fact that, today, there are neither federal programs nor federal funding for such programs. And given the fact that the federal government is swimming in a sea of red ink, the Government of Canada cannot at this time re-launch multi-billion dollar national programs to support municipal waterworks projects that, according to the constitution and to the provinces themselves, are not in federal jurisdiction.

At a time when the federal government is hard-pressed to address major priorities in its own jurisdiction, additional massive federal expenditures to meet demands for municipal water systems are unrealistic. These are additional funds because the federal government is already handing over tens of millions of dollars to help provinces provide such essential services. It is doing so, either directly through special projects, or indirectly through broad transfer programs and federal tax exemptions. There is no more fiscal room to expand the federal government involvement.

Fact: Each year, the Government of Canada has been racking up $30 to $35 billion deficits to the point where the accumulated debt is $300 billion.

Fact: In 1975, only 12 cents of every dollar spent by the Government of Canada went to service its debt; today, 33 cents of every dollar go for that purpose. By contrast, the provinces spend only 10 cents on debt service charges out of every dollar they collect while, for their part, the municipalities spend a mere 9 cents.

The federal government is the most severely strapped jurisdiction in the country. It cannot afford to pay its own bills, much less someone else's. Indeed, because we are talking about a magnitude of expenditure for which no jurisdiction has the money in the bank, both the provinces and the municipalities are in a better position than the federal government to absorb new debts for municipal waterworks.

If a case can be made for increasing the federal role in municipal infrastructure, it will have to be made in the context of existing federal programs and expenditures, for example, through mechanisms of federal-provincial economic and regional development agreements (ERDAs), which are already so effective in other policy areas.

Please do not interpret my remarks as a lecture on fiscal responsibility. I am simply stating the bald facts. And the baldest fact of all is that the federal government is not a Holy Grail, least of all is it a honey pot into which Canadians can dip. The federal government is Canadians, spending their own tax dollars.

There are not three taxpayers in Canada - federal, provincial and municipal - however much fiscal arrangements may be organized as if there were. There is just one taxpayer. When provincial or municipal politicians in Toronto or St. Catharines, or anywhere else in Canada, call on the federal government to pay the bill for their programs, they are really asking all Canadian taxpayers to do so. And, because the money needs to be borrowed, ultimately the next generation and generations after them, are being asked to pay.

Seen in that context, is the call for federal subsidies for municipal infrastructure enlightened public policy? Or merely a new way to pass the buck? Worse still, doesn't buck-passing perpetuate water mismanagement in Canada by making it easier to avoid real solutions?

Any genuine search for solutions must start by addressing the fundamental problem of overuse and abuse of water. That, in turn, requires us to deal with the lack of a realistic pricing policy. The basic problem is that only a few Canadians are now required to pay a fee approaching the actual cost of the water they use. In Edmonton,

for example, the price for 20,000 litres of water a month, the typical family consumption across Canada, is $22.55. In Toronto, where, like Calgary, some sections of the city are metered and some are on a flat-rate, those 20,000 litres cost $9.90 unmetered and $10.62 metered. In Ottawa, the charge for the same quantity of water is nearly twice as much, $18.42. In my home town of Charlottetown, the corresponding charge is a mere $7.67. Because water is underpriced, it is undervalued. And like any undervalued product, it is taken for granted and wasted.
Fact: Of 368 municipalities surveyed in Canada, almost a third levy flat-rate charges only, and another 44% use some form of flat-rate pricing. Of the few that charge according to use, two-thirds actually reward high usage through declining block rates. In other words, most Canadian municipalities, as a matter of policy, promote inefficient water use.

Almost everywhere in Canada, people in the same province, in the same city, even those living within blocks of one another, pay markedly different rates for their water, with little but happenstance to explain it.

Not only are Canadians out of step with one another concerning water prices, they are also out of step with the rest of the developed world. Last September, the American Water Works Association reported that, in water prices charged to businesses, and there is no reason to believe that domestic consumption rates are comparatively different, amongst 10 industrialized countries, Canada charges the least. Overall, Canadian industry pays about a quarter of what European industry pays and about half of what U.S. industry pays for water.

Canadians have said, again and again, that they are prepared to pay reasonable costs to protect their environment. What could be more reasonable than to insist that all Canadians pay the true cost of maintaining, rehabilitating or, where necessary, building treatment and delivery systems for their life-sustaining water?

The problem is not money. It is priorities. Let me give you just one example. People in Saskatchewan and Nova Scotia have almost precisely the same average weekly income, and the two provinces have similar levels of per capita debt. But water is a cherished resource in Saskatchewan, where 99% of municipal sewage is treated. In Nova Scotia, by contrast, only 21% is treated. In other words, a community's management of water can express, not its financial position, but its political will.

The quality of the water Canadians need and use is not going to improve until we sit down and do the fundamental thinking and planning that we have been avoiding. Needed, in particular, is a rationalized pricing system in Canada, one that is sensitive to local and regional conditions but that is also geared to doing three things everywhere in Canada:

- encouraging people to conserve water;
- raising the funds needed to build and maintain costly water systems;

and

- encouraging technological innovation that will slash capital and operating costs.

Convening this conference on infrastructure is a step towards those goals. At the next such conference, as a logical step, some of these crucial issues should be considered:

- Take a hard look at water pricing, which is the key. Right now, we lack sufficient information even to determine the real costs of supplying water and wastewater services on a community-by-community basis. Not surprisingly, therefore, we also lack the data on the effects of rate-structure changes.
- Assess the relevance of water pricing in other utility sectors, garbage collection, hydro and the like, as well as the experience in other countries;
- Evaluate more efficient ways to organize water and sewage treatment services, including alternatives to public-sector service and opportunities to commercialize that service;
- Examine current technologies, and the development of new ones, for water delivery and wastewater treatment and for the rehabilitation of underground systems;
- Evaluate financial incentives and disincentives for private-sector initiatives, including tax concessions, venture capital, and government guarantees;
- Discuss industrial discharges to sewers, and the need to develop and apply sewer-use by-laws, as well as other water-related policies; and
- Finally, look at how to boost the Canadian clean-water industry, which now employs 60,000 people and which could become a major Canadian export earner.

On behalf of the Government of Canada, I offer to co-sponsor such a major conference with the Federation of Canadian Municipalities. I have in mind a high-level meeting of decision-makers to craft workable solutions to the problems that will have been identified by the end of your deliberations tomorrow.

In the meantime, the federal government is launching programs that will make water management more efficient and less costly. One of our greatest successes is in technology development. A case in point is a multi-million dollar federal government-private sector oil-from-municipal sludge project that may revolutionize the way cities around the world dispose of waste.

In fact, according to experts, starting today, we could save hundreds of millions of dollars in sewage treatment over the next 5 years, by using Canadian-developed computer-automated process control, not including other savings we could expect from more intensive research. I urge you all to investigate these developments. New York and other cities throughout the world wish to gain access to the technology.

Of particular interest, perhaps, will be efforts to extend the life of existing water systems, thereby deferring the need for major capital expenditures until, with effective pricing policies, they can be paid for.

For its part, the federal government will keep working on developing those new technologies. Moreover, we are already taking steps to meet our responsibilities at such Federal facilities as army bases and airports. And we are eager to collect information from around the world, and funnel it to our provincial and municipal colleagues, especially on solutions to specific water infrastructure problems.

Water is a precious resource. We owe it to ourselves, and to generations of Canadians yet unborn, to use it with care and to ensure it remains healthy and clean for the future.

MUNICIPAL INFRASTRUCTURE RENEWAL: A TRADE UNION'S POINT OF VIEW

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ABSTRACT

Three themes are used to emphasize the concern of CUPE's members with respect to the need to restore and maintaine Canada's urban infrastructure. The first relates to the issue of free trade and government spending as it affects the flow of money; the second to the long-term savings that could result from on-going maintenance of urban infrastructure; the third to the cost of contracting verses the use of public employees to perform community tasks.

RÉSUMÉ

L'auteur se sert de trois thèmes pour faire ressortir les préoccupations des membre du SCFP à l'égard de le restauration et de l'entretien des infrastructures urbaines du Canada. Il parle d'abord de l'incidence du libre-échange et des depenses du gouvernement sur le flux monétaire et fait ensuite mention des économies à long terme résultant d'un entretien constant des infrastructures. Enfin, il compare le coût de l'affermage des travaux publics à celui de leur exécution par la fonction publique.

My union, CUPE, includes approximately 125,000 employees of municipalities from coast-to-coast, by far the largest single industrial or jurisdictional group within our overall membership of 330,000. So we in CUPE are naturally concerned about the future of our communities, and are vitally interested in the whole question of municipal infrastructure. We know that revitalizing that infrastructure will require an enormous commitment of public resources and a strong dose of political will. And we aim to help in the process of drawing out those resources and that political will.

Why? Partly because it's in our members' interest. And partly for reasons of public conviction.

Let me elaborate those two points by placing the issue of municipal infrastructure revitalization in context from a trade unionist's standpoint. To do so, I will be grouping my observations under three themes.

FIRST THEME

There has been a good deal of talk lately, mostly emanating from the government, about developing a cozier relationship with the United States. The current federal government seems to be staking its future on a free trade deal. And Canadians are subject to a daily barrage of debate on U.S.-Canada relations. The view from the top seems to be that we would all be much better off if we got even closer to the Americans. But some, if not all, of us here today are aware that there is at least one area where we Canadians may have it all over our American friends, the way we organize and care for our communities.

A couple of anecdotes may illustrate what I mean. In his recent book on life in the U.S., Washington-based columnist Allan Fotheringham says that he is reminded daily about the differences between Canada and the United States as he drives to work: "It is like driving through Beirut," he says. "The pavement dips and dives and descends into craters. The surface undulates; it is patched with steel plates that tear your tires; it sinks into gullies and raises horrendous bumps ... The city budget is so bare that the street system is a joke. This fact will come as no surprise to anyone who has been to New York ... Philadelphia, Chicago and Detroit." Fotheringham says that each time he returns to Vancouver he suffers culture shock on the way in from the airport. The taxi rolls smoothly! There are no jolts to the spine.

Then, there is the story that is quickly becoming folklore, of the American film director who, while shooting a movie in Toronto, complained about the condition of the city's streets. They were much too clean for the outdoor scene in the movie that was supposed to be taking place in New York. His solution was to buy a truckload of garbage and strew it over two downtown city blocks, thus creating, apparently, a more believably grimy appearance. The filming proceeded smoothly until the movie crew decided to take a lunch break. While they were gone, a City sanitation crew (all CUPE members, incidentally) happened by. They were horrified by the mess, and proceeded to clean it up before the movie makers returned. The furious director had to order more garbage before he could finish the day's shooting. Later, when the municipal workers were told why the garbage had been dumped there, and they had to explain themselves, they suggested that in future they be given some advance notice. One of them explained, "Our job is to make sure that Toronto does not look like New York".

I think that these two little stories illustrate a truth. Canadians appreciate what they have here in Canada and do not want to become more like the United States. They may take many municipal amenities for granted. They may not want to pay for them. But fundamentally, they are aware of the quality of our cities and towns. Canadians know that our communities are cleaner, safer, better planned and generally better maintained.

But will we always be so comfortable and confident in making those comparisons? Here's where I get a bit concerned. When New York City was facing bankruptcy a few years ago, and desperately appealed to President Ford in the White House for help, the famous headline in the Daily News summed up Washington's response: "Ford to New York: Drop Dead."

Now Canadian cities and towns (although not in any sense bankrupt) are asking Ottawa for help. Funds are necessary to do badly needed repair work on deteriorating roads, bridges, sewers, water supply systems and other municipal facilities. However, when the FCM asked Ottawa for help, one third of $15 billion over 5 years, to be precise, the Minister of Finance, Michael Wilson, put a lock on his chequebook. He says that municipal services are no business of the federal government; it's up to the municipalities themselves and the provinces to foot the bill.

Michael Wilson may have every constitutional right to refuse help to Canadian cities and towns. But does that make economic sense? Does it make social sense? According to FCM estimates, around 60,000 jobs a year would be created through their proposed infrastructure repair program. At a time when more than one million people are out of work, this proposal looks like a winner ... a solid public investment not only in job creation today but also in the future of our communities tomorrow.

The FCM's proposal calls for a lot of money, almost a billion dollars a year for 5 years.

The federal government may argue that Canada has to cut spending in order to reduce the federal deficit. But in fact, one of the main causes of the deficit is the very policy of fiscal restraint that the federal government has been following for the past decade or more. That restraint has stifled the economy, depressed real incomes, reduced output growth, and reduced tax revenues. The most dramatic result: massive unemployment. Unemployed people don't pay taxes. Instead, they become a multi-billion-dollar drain on the finances of all levels of government and that helps keep the deficit high.

Then there are all the myths about government spending somehow hurting private business, as if public and private sectors were somehow in conflict. Yet in fact, the two are so interdependent that it is difficult to distinguish between them.

Most goods and services are produced through the combined effort of both the public and private sectors. Consider these facts:

- governments in Canada now spend about $70 billion a year on private sector goods and services, including everything from paper clips to communications satellites to roads on which companies deliver their goods to market;
- government payrolls amount to another $60 billion, most of which is also spent by individuals on goods produced by the private sector;
- governments at all levels also transfer about $50 billion a year to needy people in the form of welfare, unemployment insurance, and other support payments. Most of this money, too, finds its way into private business; and
- $20 billion that goes directly from the federal government alone to corporations in the form of handouts of various kinds.

This vast amount of government spending directed into the private sector adds enormously to corporate profits and dividends, and creates an estimated four million private-sector jobs. So when I hear Mr. Wilson complaining about government spending, I wonder what in the world is he talking about?

SECOND THEME

Trade unionists know that doing municipal infrastructure work now, maintenance and renewal, is productive and useful and will save money for the taxpayers in the long run. But there is an equally important reason for ensuring that our cities and towns are well serviced and maintained: The role of urban communities themselves is becoming more and more important in the country's economic future. That future already depends very much on cities and towns and on the service sector activities within them. All predictions point to the fact that by the year 2001, the greatest area of employment growth will be in jobs related to urban centres.

This view is supported by a recent study of the service sector in Ontario. Canada's economy is dominated by services, which now account for three-quarters of all employment and almost three-quarters of Canada's gross domestic product. That's where the jobs are too: finance, insurance, real estate, employment and personnel services, computer services, health care, education and so on, most of them urban-based. In Ontario, for example, 162,000 persons are employed in hospitals, compared with 92,500 in the auto industry. Universities and colleges employ 64,000 Ontarians, compared with 38,300 in basic iron and steel mills. About 80,000 Ontarians work for municipalities. These activities are all urban-based.

And as we're talking about growth and jobs and how to create them, we must not forget the findings of the Informetrica study; a study commissioned by the FCM to evaluate the macroeconomic impact of their public-spending proposal with respect to infrastructure renewal. That study shows that spending on infrastructure tends to have one of the highest multipliers, i.e., one of the highest impacts on output, employment and incomes. And it shows that expenditures on infrastructure create 300% more jobs than a comparable cut in corporate taxes.

Unfortunately, real spending on infrastructure just hasn't kept pace. Real capital expenditures by all levels of government increased by only 2.5% between 1975 and 1985, although the real economy expanded at about ten times that rate (26%) over the same period. That is a self-defeating approach to economic development and it must cease. As the FCM has said: "As a society, we are being penny wise and pound foolish."

In the 1980s, so-called "big government" has come under attack. Government, its critics charge, is bloated and unproductive. The private sector, on the other hand, is always at the ready to spring into action and provide productive jobs. The private sector produces things that are "real" and can be measured; the public sector is just a drain on our economic resources, they say.

But what is really of value to our society? And what is really of value to the economy? Does the manufacture of chewing gum provide more value than the operation of a public library? Is the real estate entrepreneur who "flips" property for quick profit more productive than a municipal engineer or a social worker? The ongoing denigration of the public sector on the one hand, and glowing praise of the private sector on the other, serve only to perpetuate the myth that anything done by government is economically useless and that only the zeal and dynamism of the private sector can create growth and jobs.

When a private business builds a new plant or installs new machinery it is said to be making an investment. It is increasing its productive capacity. There is great cheering when this happens. We applaud each and every such show of "investor confidence". When money is borrowed to pay for these expenditures, that is seen as a wise use of credit. It is understood that the liability incurred will be offset by the value of the asset acquired.

When the government does the same thing, such as build a trunk system, a bridge or new hospital or park, a different terminology is used. Government is spending, maybe even running up its deficit. Here's the difference: business makes an "investment"; government makes an "expenditure". The fact is that roads and sewers and bridges and hospitals and so on are an investment by government, an investment in facilities and services for people and for business. Private business depends on these services. (True, it may be argued, as some lunatic ideologues do in the States, that industry could construct roads and build bridges on a user-pay basis. But who would want that? What kind of society would we have then?)

In Canada we want to live in a society where society's executive arm, government, ensures the provision of certain essential services. When government is allowed to play that role, we can have both an efficient and a civilized society. But the scorn too often heaped on the public sector is increasingly keeping this from being done. For example, we are increasingly told by business and government leaders that "throwing money", as they put it, at public works programs at best provides temporary relief from the unemployment problem. As if this assertion is a telling example of public sector "failures".

Yet, over the years, winter works-type programs have never been intended to give anything but temporary relief. But that is their inherent problem, that they have been just stop-gap political measures that were not planned and had no hope of significantly affecting unemployment.

That is not what should be done. Instead, it is time for a serious, coordinated approach to dealing with unemployment through public stimulus of the economy through public investment. And an integral part of that investment should be the repairing and renewing of the infrastructure of our urban communities.

THIRD THEME

We as trade unionists know that the public is with us and with the FCM on this issue of infrastructure renewal. Despite continuing negativism from some of the business community, the anti-government revolt (if there ever was one in Canada) is over. The public now favours more spending on public sector activities such as cleaning up the environment, job creation, and services for people. For instance, in a recent public opinion poll, 81% of Canadian adults favoured more government spending on job creation. This is where the FCM's proposal is very strong politically as well as economically. The studies commissioned by the FCM show that their proposed infrastructure revitalization program would result in a 5-year cumulative increase in employment of 285,000 person-years, or 57,000 jobs per year.

That leads to the question, however, who will employ all those workers required to bring our streets, sidewalks, parks, bridges, water and sewer systems back to acceptable standards? In other words, what kind of job creation should the FCM proposal aim at delivering? The Informetrica study has given one important piece of information in this regard: It has shown that apart from manufacturing jobs, the overall positive impact of the program on the economy would be the same, whether the work was delivered by contract employment or by employees working directly for municipalities, as long as they are equally productive and receive equivalent compensation.

I want to use this opportunity to let you know what we in CUPE would like to see happen. Because we have strong opinions about this aspect of the subject matter also, as you can imagine. First, we think that at the very least, laid-off municipal public works employees, parks employees, etc., those who are available to work and want to work, should be rehired. Over the past few years, there have been sharp reductions of hard-service departments in many communities. For example, the permanent work force in the construction division of the City of Edmonton's water and sanitation branch dropped from 481 to 161 between 1982 and 1985. Right across Canada there are thousands of laid-off civic employees who have given years of loyal service to their communities. These people can do the work, are available for work and want to work. They should be given priority for any employment opportunities arising out of infrastructure renewal.

But what about the additional employees that will be required? It is our view that wherever and whenever feasible, the work should be done by workers hired directly by towns and cities. However, we are not unrealistic. We understand that some specialized functions will need to be contracted. The cost of operating otherwise would simply be prohibitive. But a large portion of the work, a very large portion, can be done in-house and should be done in-house. We've looked quite closely at the alternative, known as contracting-out. It's a problem our union contends with day-in and day-out. Our experience and our studies indicate that from the perspectives of efficiency, long-term planning, quality control, cost effectiveness, flexibility, and citizen satisfaction, it makes common sense that as many services as possible be performed in-house, rather than resorting to middle-man contractors.

Why? In a nutshell, contracting-out results in the fragmentation of municipal services and the loss of planning continuity. You lose the ability to introduce quick adjustments to the details of a project. You are subjected to the notoriously high cost of "extras" charged by contractors. You pay cost plus. And you lose effective control over the workforce and over work quality. By contrast, public employees are permanent residents of your community, concerned that a quality, citizen-oriented job will be done. Some will say, what about cost? Isn't it usually cheaper to farm-out the work to contractors? We have found it isn't. When we have been given, or we have obtained access to accurately-compiled comparative data, we have been able to demonstrate time and again that it is better for cities to side-step the middle-man, the contractor, and do the work themselves.

Recently, for example, the city of St. John's, Newfoundland and CUPE Local 569 (which represents the city's 400 outside employees) ran a carefully monitored pilot project involving the installation of sewer and water lines. Using strict accounting procedures, it was found the job cost 30% less than tendering to a contractor. St. John's mayor John Murphy said, "The public thinks contracting-out saves money. But we've proven with this project that it's just not true". (We shouldn't forget, after all, that most public works departments across the country find their origins in the recognition that contracting-out proved too costly, was inefficient, was open to many different abuses, and created a tendency for quality to suffer.)

Listen now to Jack Thompson, Manager of Parks Operation for the City of Regina, responsible for parks construction, maintenance, and landscaping. He had 25 years experience in the private contract business before becoming a city manager. He said, and I quote: "The private sector must include a profit margin. Automatically the public sector is provided with at least a 20% advantage." And he went on to say, "The popularity in recent years of the contracting-out syndrome has been fostered by the wishful thinking of misguided, poorly trained, and poorly informed decision-makers". Yes, these are strong words. But let me tell you those words ring true. We have carefully studied and scrutinized what passes for documentation supporting contracting-out, and time and again we've uncovered unsupported assertions, statistical flimflamming, and gross bias.

How can contracting-out be cheaper than municipal service? Especially when there's no built-in profit margin and when wage rates for municipal construction workers are most often lower than the going trades rates in their communities. Yes, setting aside all other factors such as quality, openness to abuse, etc., if a contractor uses non-union workers, and pays poor wages, he can often carry out a job more cheaply. But this, I would hope, is not the standard our cities and towns are interested in promoting. Remember, the FCM's program is based on the supposition that revitalized public works and public amenities will make the Canadian economy stronger and the lives of individual Canadians safer, more secure and more agreeable. That objective surely does not square with the impoverishment of a whole sector of the workforce through the short-sighted practice of contracting-out. Nor, I assure you, will working people and their unions sit by and let that happen.

In closing, it's long overdue, in my view, for public officials and public employees to stop being apologetic about the public sector, or about the very important work that is carried out by our public institutions. There's nothing inherently better at all about the private sector. And when it comes to the ability to carry out accountable planning, to ensure durability and quality, and to adhere to community standards of excellence, the public sector takes a back seat to no one.

So, with this in mind, I again pledge CUPE's endorsement and support of the FCM's ambitious program of urban revitalization. I also offer the support of my organization when approaching senior levels of government. The fact that we represent the majority of workers employed by civic governments (and are the largest union in Canada by far) should, I think, lend credibility to any approach the FCM makes to the federal government.

We believe in our nation's future, and that that future should be based on one of Canada's major and special assets: our liveable urban communities. We are ready to play our part in making the case to government to ensure the survival of those assets. And we are ready to play our part in reminding Canadians in general of the importance of Canada's unique and, we think, better and more caring society on the northern half of the continent. We look forward to working together with you and with the FCM to achieve those vital goals.

REHABILITATION OF MUNICIPAL SERVICES IN YELLOWKNIFE. NORTHWEST TERRITORIES

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ABSTRACT

The City of Yellowknife (population 14,000) is actively pursuing an upgrading program directed at replacing aging cast-iron watermains and corrugated-metal sewer mains in its downtown core. This cost-shared project with the Government of the Northwest Territories was initiated after careful study and hands-on observation had revealed that the sewer system in particular was in imminent danger of collapse. Although this paper will address the necessary rehabilitation of the water, sewer, and storm sewer system, the City's roads, public facilities and buildings are also in need of upgrading.

Concurrent with the ongoing rehabilitation work is a building boom unprecedented in the City's history. Over the past 2 years, building permit values have averaged approximately $45 million per year compared to an average of approximately $20 million per year for the previous 2 years.

The combination of an aging municipal system and very significant growth and demand for services has made for challenging times from the public works perspective.

RÉSUMÉ

La Ville de Yellowknife (population de 14,000 âmes) a lancé un programme de remplacement des réseaux d'aqueduc et d'égoûts de son centre-ville. Les conduites d'eau de fonte et les collecteurs d'égoûts en tôle ondulée se font vieilles. Ce projet dont les frais sont partagés entre la ville et le gouvernement des Territoires du Nord-Ouest, a été mis en oeuvre après qu'une étude détaillée ait démontré la rupture imminente du réseau d'égoûts en particulier. Cet article ne porte que sur la réhabilitation des réseaux d'aqueduc et d'égoûts même si le programme de construction inclue le réaménagement des rues du centre-ville.

Les travaux de réhabilitation en cours surviennent en même temps qu'un essor de construction sans précédent dans l'histoire de la municipalité. Depuis deux ans, la valeur des permis de construction a atteint une moyenne de $45 millions par année comparativement à $20 millions pour chacune des deux années précédentes.

Le déclin des réseaux de service du centre-ville en période de grande croissance économique présente un très grand défi au Département des Travaux Publics.

INTRODUCTION

The City of Yellowknife is located on Yellowknife Bay on the north shore of Great Slave Lake. As the capital of the Northwest Territories, the city has grown since 1945 from a mining and supply centre with a population of 2,500 to its current population of approximately 14,000. The city has developed into a modern northern metropolis with a highly-developed commercial core including many multi-storey commercial and residential buildings.

Yellowknife is in many ways a typical small city. Yet in many more ways, it is perhaps unique in Canada. Situated on the Precambrian Shield in a zone of discontinuous permafrost, building conditions, particularly as they affect the installation of municipal services, are far from ideal. Current municipal services encompass a full range: from underground utilities installed with the latest technology in mind, to a minimal level of service consisting of a barrel for water storage and a pail for wastes.

Throughout the first three to four decades, Yellowknife was a community whose growth and development was very gradual. Municipal services were premised on this slow but steady rate of growth. Over the past few years, however, the growth pattern has changed significantly. The gradual upward growth has exploded at an almost exponential rate.

As a result, services are being taxed to their maximum, yet projects and development schemes are being proposed almost daily.

One would be correct in saying that Yellowknife has progressed from a mining settlement to a vibrant northern city in a period of 50 years. However, a great deal of this development has occurred in the last decade. This fact alone makes the rehabilitation of municipal services in Yellowknife an integral component of the city's continued development.

The city is far more modern than one would expect under the circumstances. All amenities with rare exceptions are available to the citizens of Yellowknife. Under these conditions the demand for a very high level of service for all facets of public works is ongoing.

The downtown area originally constructed to service only single-family residences is now the scene of a proliferation of high-rise commercial and residential buildings. Our city is in its infancy when compared to counterparts in southern Canada, yet the servicing expectations of the citizens of Yellowknife are every bit as high as they are in the south. To satisfy these expectations with a municipal system that literally is collapsing presents a significant challenge. As if dealing with rapidly deteriorating municipal systems were not enough, coping with what may be viewed as the greatest building boom in the city's history adds to the challenge.

The installation of municipal services to the Central Business District (CBD) incorporated cast-iron watermains and bituminous-coated CMP sanitary sewers. In recent years the city has experienced hydraulic capacity and structural problems with the municipal services in the CBD.

Non-municipal project-related building permit values have increased significantly over the past 2 years. When analyzed on a dollar value of building permits per capita basis, the values are much higher than those being experienced in any other city in Canada. The need for a renovated, reliable system never has been greater.

The rapid growth in the CBD, particularly with respect to multi-storey development, was not anticipated when the services originally were constructed and much of the system, especially the sanitary sewers, shows signs of hydraulic overloading. The CMP sanitary sewers have, in recent years, been showing signs of major structural deterioration resulting in blockages and collapses.

The system has broken down on countless occasions. A myriad of watermain and sewer breaks, coupled with ongoing extensive maintenance associated with manholes, has placed a strain on the city's limited manpower and financial resources. An experienced and dedicated Works Department staff have kept up with the emergency repair work and managed to avoid catastrophic failure.

The cast-iron watermains have also shown indications of corrosion problems, particularly with regard to the bolted joints. This deterioration has resulted in several watermain breaks.

In response to these problems, the city undertook a detailed study in 1983/84 to evaluate the condition of the municipal services in the CBD and to establish a program for upgrading the CBD to a standard of servicing similar to that provided in new development areas. The study recommended a comprehensive plan for upgrading the sanitary sewers and watermains in a three-phase program at an estimated cost of $10 million.

The first phase of the implementation works was undertaken in 1985 at a cost of $3.5 million. The total project is scheduled for completion by 1989.

WATER SUPPLY SYSTEM

A recirculating water distribution system, similiar to that constructed in Flin Flon, Manitoba, in the early 1930s was used. In this system water is preheated, circulated through dual mains and dual house service connections, with a portion being returned to the main distribution pumphouse.

Prior to 1969, the water for the city, as well as for Giant and Con Mines, was obtained from three separate intakes in Yellowknife Bay. In 1969, a new water intake and pumphouse were constructed on the Yellowknife River near its mouth. A 400 mm diameter submarine pipeline in the bottom of the bay delivered water to serve the city and both mines through the pumphouse on Yellowknife Bay. This lake pumphouse (Pumphouse No. 1) also was upgraded to meet the city's increasing water demand and to supply water to the Central Business District and adjacent subdivisions.

In 1971, the 2,270 m^3 reservoir, which receives water from Pumphouse No. 1 and Pumphouse No. 3, was added to the system to meet the demands of the new development west of the city, including Matonabbee, Forrest Park Stage 2, Northland Trailer Park, the hospital, and the correctional centre.

In November 1978, Pumphouse No. 4, along with a 5,680 m^3 reservoir, was constructed to meet the requirements of the development at the southern end of the city, namely the new Frame Lake South Subdivision. This pumphouse was sized to meet the ultimate demand of the subdivision for a future design population of 10,000.

The water distribution system in the CBD and surrounding residential areas consists mainly of ductile-iron supply lines 150 to 200 mm in diameter and single return lines 100 mm in diameter. Most of the services to the lots are uninsulated and bleeders still exist in some parts of the city to prevent freezing during the winter.

The city has recently completed an upgrading of the system to meet the fire flow requirements of the CBD and the surrounding areas. A 300-mm diameter water system was completed in 1984.

SANITARY SEWER SYSTEM

Sewage treatment for the city began in December 1949 with the operation of a primary mechanical treatment plant that permitted settling and digestion of solids in the effluent.

The treated effluent was discharged into Niven Lake, overflowing into Yellowknife Bay. The use of the plant was discontinued in 1962, when Niven Lake was converted into a facultative lagoon. In 1964, a primary short-detention pond was added to the lagoon to increase the treatment efficiency.

As development progressed, a major lift station was constructed in 1973/74 to service the area of Forrest Park. In 1977, a temporary lift station was installed to pump sewage from the Frame Lake South Area 3 development into the gravity collection system discharging into Kam Lake via the Franklin Avenue trunk sewer.

In 1981, the Kam Lake Lift Station came into operation, pumping effluent into the Fiddler's Lake Sewage Lagoon System. A new lift station at 49 Street/52 Avenue was added in 1983 to improve the overall disposal system for the central city core and reduce loading on the School Draw Lift Station.

In summary, the current sewerage system is made up of several gravity sub-systems and seven lift stations, i.e. the School Draw, Gitzel, Albatross, Forrest Park, Frame Lake South and CBD lift stations collectively pumping into the Kam Lake Lift Station. An emergency overflow is provided at the Kam Lake Lift Station which will discharge to Kam Lake in case of a station failure. This station is designed to handle all of the city's sewage which is pumped via a force main to the Fiddler's drainage area west of the city for treatment.

The Fiddler's Lake sewage treatment system incorporates a series of lagoons to provide anaerobic and facultative treatment of the city's sewage and eventually discharges towards Great Slave Lake through a number of lakes and water courses.

Most of the city's original collection system consists of corrugated-metal pipe 200 mm in diameter. Asbestos-cement and ductile-iron sewer pipes are also in service in three newer areas of the city. Manholes are predominantly of concrete block construction with frost covers to help prevent freezing.

THE PROBLEM

Water Supply System

The original system installed consisted of 1.82-m uninsulated flanged sections of cast-iron pipe bolted together.

According to observations made during from ongoing maintenance and upgrading of the water system completed in 1984, the pipes themselves appeared to be in reasonable condition and unlikely to require replacement for 10 to 12 years. It was noted, however, that the bolts through the flanged joints were rusting away, although there were few signs of external corrosion.

The original intention was simply to replace the bolts on the water lines concurrent with the replacement of the sewer main.

Storm Sewer System

Prior to upgrading having been initiated, the existing storm drainage system for roadways in the CBD was provided only on the major road network. Installation of the limited storm sewer network was undertaken after the new townsite was first serviced.

Some of the catch basins on the system were cross-connected into the sanitary sewer system, resulting in overloading of the sanitary mains in the affected areas during run-off periods. The system was examined and it was determined that only four locations existed where catch-basins were tied to the sanitary system. Steps were taken to eliminate these cross-connections.

In general, the existing system is functional for the present stage of development, but will require significant upgrading as future development in the CBD occurs.

Sanitary Sewer System

The corrugated-metal sewers had originally been installed with an insulating layer of moss. A combination of acidic ground conditions, naturally corrosive water, and a less than ideal choice of construction material had resulted in significant deterioration of the system. Ongoing and sustained repair of sewer breaks, which were occurring regularly, revealed that in many cases the pipe was badly deteriorated and had all but disintegrated.

A closed-circuit television inspection survey was undertaken for the city in September 1977 to determine the internal condition of the sewers. This inspection report revealed corrosion of the pipes, locations of leaks, and obstructions in the lines. Several sections of collapsed and broken pipes, and overflow conditions also were observed.

The system functioned effectively from the time of its original installation in the late 1940s until early 1976 when the sewers started to show signs of collapse, and corrosion of the corrugated-metal pipes was detected.

Prior to initiating the major upgrading program, approximately 1,330 metres of the laterals and collector sewers had been replaced with pipe of similar type and diameter.

Examination of sections of pipe exposed during a test pit program confirmed that corrosion of the existing corrugated metal sewers was very extensive. The grades and sizes of some sections of pipe were inadequate to meet the present sewage flows and the system exhibited sections of collapsed pipe and leakage at service connections to the laterals and collector sewers. In most cases, it was noted that service connections project into the sewer pipe, creating obstructed flow conditions. This examination, together with the information available on the general condition of the sewers from the replacement program and the camera study undertaken in 1977, revealed that a major rehabilitation program was needed to provide an efficient and workable system both for the present infrastructure and for future development.

On the basis of this review it reasonably can be assumed that the intensity of corrosion throughout the central area system would be similar to that revealed in the test pit program. It was estimated that the remaining service life of these sewers was in the time frame of 0 to 5 years.

It may be appreciated, however, that the extent of corrosion varied from location to location and it was not possible to forecast a pattern of failure with any degree of certainty. Failures to date have occurred in a random manner over relatively short sections.

However, a major sewer collapse would clearly cause a disruption to the collection and disposal of sewage and have a serious impact on the downtown area. Consequently, it was recommended that the sanitary lateral system within the downtown area be completely replaced and that this replacement be implemented immediately.

The coated, corrugated-metal pipe used for the original sewer system is not normally used for sanitary sewers under the ground conditions encountered in Yellowknife. This type of material could have reasonably been expected to deteriorate over a period of time. However, the system had to be replaced much sooner than would have been the case had the sewers been constructed more conventional materials.

THE SOLUTION

In late 1983, the city commissioned a study to review the entire system of sewer and watermains in the Central Business District. The study, completed in mid-1984, concluded that the sewer system in this area was in an advanced state of deterioration and that the chance of serious failure or collapse was high. It was also concluded that the majority of the sewer system in the CBD was undersized to meet either current or long-term demands. This factor, together with the advanced state of deterioration, precluded the possibility of using more innovative methods of pipe renovation. The study recommended that the city undertake a major replacement program and that work be undertaken in three phases, with the areas that had been defined as the most critical being reconstructed during the first phase. The program recommended that Stage I be undertaken in Year 1, Stage II in Year 3 and Stage III in Year 5. The time between phases was proposed to ensure that the first phase would be completed prior to the commencement of the second phase and so on. As a result of the complex nature of the work, the restricted working conditions and the relatively short construction season in Yellowknife, it was not known whether each phase could be completed in one construction year. (A construction year in Yellowknife may be approximately defined as the period from June 1st to September 15th.) The project was approved, and construction of Stage I was undertaken in 1985.

Stage I Construction

Design work for Stage I of the reconstruction program commenced in late 1984 and was tendered in mid-March, 1985, with tenders being received on April 10th, 1985. The project entailed the total replacement of the sewer lines, including manholes and services, together with the replacement of the corroded bolts on the existing cast-iron watermains that had been constructed at the same time as the sewer mains.

When the tenders had been received, the low bid was substantially less than that of the second submission, and the decision was made to replace the cast-iron watermains rather than merely replace the bolts. This proved to be an astute decision. Although periodic observations revealed that the cast-iron mains were in reasonable condition, the corrosion was much more extensive than had been determined from spot checks.

It was estimated that the cost of undertaking the work concurrently with sewer replacement would be substantially less than issuing a separate contract for watermain replacement. As a result, it was decided to proceed with the replacement of the watermains where they were adjacent to the sewer mains being replaced.

Work commenced on the reconstruction project at the beginning of June and it quickly became apparent that the water system was in a more advanced state of deterioration than had been expected. Large amounts of scaling and mineral build up had occurred in the majority of the pipes. It also was noticed that the majority of the collar bolts were badly rusted and removal would require cutting with a blow torch. The existing uninsulated watermains were replaced with pre-insulated ductile-iron pipe. The greatest deterioration was noted on fittings and valve chambers. The valve chambers were in particularly poor condition and many simply fell apart when the soil was excavated around them. Most of the chambers had large amounts of soil and sediment covering both valves and fittings which had contributed to their accelerated deterioration. The sediment had entered the chamber through the poorly-constructed walls. Generally, the existing hydrants were found to be constructed of a "dead end" configuration and were changed to a U-type circulating configuration to reduce the risk of freezing.

The condition of the water chambers required that almost all be replaced, whereas the original contract documents called for only one chamber to be constructed. The water chambers were reconstructed to accommodate the valves and fittings and allow periodic maintenance.

The sanitary sewer system was replaced using ductile-iron pipe. During excavation it was noted that the existing pipes were badly corroded; in fact, it was virtually impossible to collect any intact pieces of pipe. All manholes were replaced because the existing manholes were either in need of repair or the existing invert was at the incorrect level for the new pipe inverts.

It had been anticipated that reconnecting the services to the newly constructed sewer mains might be a problem as a result of the extensive use of "no corrode" pipe in the existing service connections, but, very few problems were encountered.

A problem was encountered with the existing water services as a result of the wide variation in the size of the services to properties of a similar nature. This resulted in a substantial amount of surplus material. In future stages, a different approach will be used to standardize the size of services.

Generally, the project progressed satisfactorily with a well-qualified contractor undertaking the work. The most difficult conditions were encountered in the 6-m lanes where the working area was extremely restricted. The contractor made every effort to ensure that services to properties, both water and sewage, were continuously maintained. The water service was maintained by means of an overland temporary supply, and the sanitary sewage flow was maintained by means of pumping.

Reconstruction for Future Stages

The overriding aim of the city's rehabilitation work was to install the services during favourable weather conditions. While this appears to be a very simple aim, logistics related to weather, geography, material, and labour often become insurmountable if not thoroughly and competently planned. Fortunately, some lessons had been learned from past construction experiences:

N.M. Hall of University of Manitoba, Winnipeg, who assisted in the design of the Flin Flon and Yellowknife systems stated: "Our experience at Yellowknife, N.W.T. shows that permafrost and low air temperatures present problems that differ in degree, only, from those in less severe climates. The outstanding features are:

- short construction season;
- transportation difficulties, delays, loss and breakages in transit, etc.
- local labour very poor - all skilled labour must be imported."

Clark (1950)

As a result of the experience gained in the construction of Stage I of the project, the following observations and recommendations can be made.

Acceleration of Program. When the feasibility study was undertaken, the report outlined a phasing plan which allowed a 1-year gap between stages to ensure that each stage was completed prior to the next one being started. The experience in 1985 showed that if a well- qualified and experienced contractor undertakes the work, each stage can be completed in one construction period. Consideration is being given to accelerating the program within the limits of available funding.

Replacement of Watermains. The extent of the water works in Stage I was substantially more than anticipated, but the work was absolutely essential to ensure that the water system works correctly. An inspection of water chambers within the Stage II area was undertaken after construction of most of Stage I had been completed. This inspection indicated that a similar situation exists with the water system in this area. Therefore, it has been recommended that the replacement of watermains, valve chambers, and fittings be undertaken in the future stages where the watermains are adjacent to the sewer mains being replaced.

Water Service Connections. A wide variation in water service sizes to similar properties was encountered. For example, services to single-family residences varied from 1/2- to 1-inch in diameter and even more. Since it was expected that these would be either 1/2- or 3/4-inch in diameter, materials were ordered to these sizes only. Many of the services were 1-inch diameter which is more than required for a single-family residence. It has been recommended, therefore, that the size of services to similar properties be standardized. If required, reducers will be used to standardize the size of the connections to the new mains.

Pre-Qualification of Contractors. It was decided for Stage I to pre-qualify contractors for the project as a result of its complexity. This process was followed and over 20 contractors replied to the pre-qualification invitation. From this list of contractors, a select list was prepared and only these contractors were allowed to submit a tender. The intent of this process was to ensure that only those contractors with sufficient experience and financial stability be permitted to tender. The system has worked well and the contractors who submitted tenders seemed satisfied with the process. The construction of Stage I was completed with only minor problems which in such a complex project was very satisfactory. Therefore, it has been recommended that the pre-qualification process be followed for Stages II and III.

CONCLUSIONS

The funding required for the rehabitilation of Yellowknife's underground systems is substantial and, for the most part, beyond the scope of existing budgets. But without a significant, city-crippling failure in our system, the public does not see any immediate need to commit massive amounts of funding to such a project when more high-profile projects such as new municipal buildings, swimming pools, and recreation facilities are "needed".

Municipal services have a finite life, and one reasonably may expect that services will deteriorate significantly over time.

Concurrent with the technical expertise which must be brought to bear on a typical rehabilitation project, a great deal of astute financial planning must also take place.

The conventional practice of planning for infrastructure replacement after a failure or significant deterioration has occurred, places a heavy financial burden on the taxpayer, a burden which the taxpayer understandably may be reluctant to assume.

A less painful approach to the rehabilitation of municipal services or infrastructure is to begin planning for its ultimate replacement from the moment it is purchased or constructed. Establishing some form of capital replacement reserve fund, by way of a small surcharge on water bills, for example, may well be the wisest long-term approach to infrastructure replacement.

The approach to overcoming the low public interest and lack of willingness to support infrastructure renewal appears to lie in an increased level of public education. Such a program needs to increase awareness how a municipal water or sewer system functions, the need for upgrading, and the need for proper maintenance. The expectation that greater results and enhanced productivity will be achieved with fewer resources is a fact of life in most municipalities. The staff of the City of Yellowknife have accepted this challenge. By making the consumers of the service more aware of just what is being done and what is proposed, we are meeting this challenge with gratifying results.

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UPKEEP OF MUNICIPAL SERVICES
THE TORONTO SYSTEM

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ABSTRACT

Toronto has taken the old saw, "an ounce of prevention is worth a pound of cure" to heart in its approach to the upkeep of municipal services. Its methodical approach effectively has lowered the budget both for the maintenance and the construction of such essential services as pavements, sewers and watermains.

Clearly, a detailed knowledge of the facilities constituting a particular service is a prerequisite for such an approach. Capturing and ordering pertinent data is painstaking, time-consuming and never-ending. On a small scale, such work is readily achievable. As the size of the area served increases, however, it becomes more and more daunting.

Using Toronto as an example, this paper examines the computer techniques that make it feasible to implement a methodical approach to municipal infrastructure upkeep.

RÉSUMÉ

Toronto a pris à coeur la recommandation du vieux diction - un point à temps en vaut cent - et en a appliqué la sagesse à l'entretien de ses services municipaux. Son approche méthodique lui a effectivement permis de diminuer le budget d'entretien et de construction de services essentiels comme les chaussées, les égouts et l'aqueduc.

De toute évidence, il faut très bien connaître les installations des services en cause pour procéder de façon aussi méthodique. La saisie et l'agencement de données pertinentes est une tâche longue et ardue, qui doit sans cesse être recommencee. À petite échelle, le travail s'exécute aisément; toutefois, il devient de plus en plus décourageant, à mesure que la région desservie prend de l'importance.

Se servant de Toronto comme exemplel, M. Doherty et ses collègues discutent des techniques informatiques qui permettent d'aborder l'entretien de l'infrastructure municipale de façon méthodique.

INTRODUCTION

Municipal Infrastructure in the City of Toronto represents a vast capital investment by the city taxpayers in the essential services a community requires for health, economic development, and environmental protection. The main elements of municipal infrastructure in the City of Toronto consist of

- storm and sanitary sewers;
- water distribution systems;
- surface facilities on public streets and lanes; and
- bridges and underpasses.

As a result of provincial legislation passed in 1954, water treatment, sewage disposal and refuse disposal are now not under City jurisdiction but are the responsibility of the Corporation of Metropolitan Toronto.

Infrastructure must be kept at acceptable levels of service and it is essential that methodical maintenance, repair and replacement programs be developed and implemented. This paper will describe the City of Toronto practices for the upkeep of its sewer systems, water distribution systems, and pavements; it also will refer to the use of computer techniques in this work.

FUNDAMENTALS

Infrastructure renewal is an integral part of the planning, construction, operation and maintenance and, ultimately, reconstruction of all public works facilities. During their economic life, these facilitiesare subject not only to deterioration, but also to changes in system loads and demands. To provide and maintain the level of service required by the taxpayer, detailed knowledge is necessary of both the structural and the service condition of the facilities involved.

Capturing and ordering the pertinent data is a painstaking, time-consuming, and never-ending task. Such data might include information on the type, size, shape, age, condition, capacity, ownership, location, and maintenance history, among others, for every component of the various facilities. In smaller communities this task can be carried out manually, but in larger municipalities, the correlations, manipulations, and use of data necessary to develop programs and monitor progress can be handled practically only by computer.

Access to a large computer system and the required expertise have made the automation of much of this task possible. (The City of Toronto has an investment in the various municipal facilities that exceeds $2 billion.) The Streets Inventory Master File contains details of the size, location, condition, maintenance and construction history and an indication of service adequacy on a block-by-block basis for all City and Metro facilities in the street allowance, public lanes, and easements. This information is available on-line at any City computer terminal and reports can be produced in a multitude of formats and according to a wide variety of criteria.

In smaller municipalities, the same degree of automation may be attained on a micro-computer-based system using modern database management software complemented by sufficient external disk storage.

Programs for the maintenance and reconstruction of Toronto's basic infrastructure staged over a long period have been developed over the past 20 years. What follows is a description of that endeavour and of current practices for upkeep of the sewer system, water distribution system and road network.

The Sewer System

The City of Toronto's sewer system was built in the mid-to-late 1800s and expanded with the city's growth through the early part of the 20th century. After 1945, the ability of the combined system to cope with new demands arising out of modest growth diminished and, by the early 1960s, extensive basement flooding pointed to the need for considerable upgrading.

Methods of Analysis. During 1964 and 1965 the entire sewer system of the City of Toronto was analyzed in order to relieve basement flooding and separate storm from sanitary flows. The "Rational Method" was used to determine the total storm flows in the existing combined sewers. It was then established that 70% of these flows would be drained to a new system of road storm sewers, while the remaining 30%, contributed by roof runoff and the sanitary flow, would be conveyed by the existing combined sewer system.

With the advent, in the 1970s, of new analysis and simulation methods which dealt more accurately with flow phenomena in large urban systems, the entire city system was investigated using the Dorsch Consult Hydrograph-Volume Method (HVM).

The HVM analysis allows an accurate picture of time varying hydrologic and hydraulic processes such as time-varying rainfall intensities, influence of the volume carrying capacity of the sewer system itself, unsteady flow, backwater and surcharging effects on branching. Upon completion of the HVM analysis, the cost of the original "Rational Method" sewer plan could be reduced by $14 million dollars.

The work, as originally conceived in 1966, is now almost complete. Approximately 600 km of relief works have been constructed at a total net cost of $105 million. The total length of the system is approximately 2022 km and can accommodate runoff from a design storm of a 2-year return frequency in residential areas and a 5-year return frequency in commercial areas.

Benefits of Inspection. While the major capital expenditures over the last 25 years has been for relief of the combined system through new construction, the continued rehabilitation and restoration of the entire network is of paramount importance. In addition to maintaining a detailed inventory of the sewer network, an ongoing inspection program is carried out to keep track of the condition of the network block-by-block. Since 1966, approximately 1900 km of sewers have been inspected by camera at an overall cost of approximately $2 million. The pictorial records obtained from these inspections have proven invaluable in:

- locating unrecorded drain connections;
- detecting structural defects which could lead to sewer collapse; and
- preparing maintenance programs.

The entire system is inspected on a 15-year cycle. Also, approximately 540 weirs and diversion structures, as well as storm outlets and large-diameter sewers, are inspected visually to ensure that they are unobstructed and functioning satisfactorily. From the inspection reports it is possible to determine appropriate maintenance activity. The bulk of the activity is normal sewer maintenance such as cleaning, clearing obstructions, correction of partial blockages, and minor structural repairs. The present rate of routine cleaning represents a 2.5 year cycle overall; more frequent cleanings, however, are undertaken at problem locations.

Devising Proper Equipment. Small-diameter sewers exhibiting a large degree of structural degradation have been rehabilitated by inserting a high-density polyethylene pipe into the existing sewer and then reconnecting all existing private and catch basin drains to the new liner. The cost of this method of rehabilitation, which was developed by the City, is about 35% less than that of conventional reconstruction; and there is little disruption to the travelled portions of the highway.

Since 1966, approximately 4,000 metres of small-diameter sewers have been relined at an average unit cost of $165. per metre. The technique required the development of a reamer to remove obstructions inside the existing sewer prior to lining. Figure 1 shows a reaming tool designed by departmental staff for cleaning egg-shaped sewers.

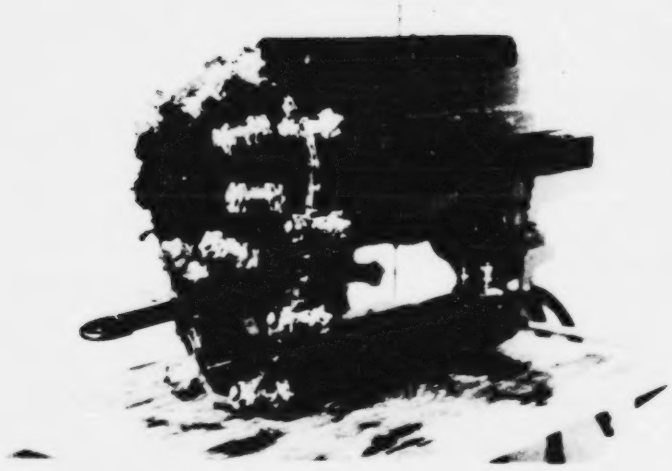

Figure 1. Sewer Reaming Tool Developed by the City of Toronto.

Bucket cleaning and hydraulic equipment are not able to remove heavy calcite deposits, roots, or protruding drain connections. The reaming tool, when passed through the length of a sewer, effectively removes all such deposits and improves the performance and operation of the existing sewer. Since 1966, approximately 16,000 metres of small-diameter sewers have been reamed at an average unit cost of $13. per metre.

Chemical sealing, when required, is carried out in conjunction with reaming. For sewers up to 450 mm in diameter, the cost of chemical sealing is approximately half the cost of conventional reconstruction.

Experimental work is now taking place on the development of a new reamer to assist in rehabilitating of the existing brick sewer system. These sewers have given trojan service to date and, while there is no pressing problem at present, the age of these brick sewers (approaching 100 years in many cases) and their location in the downtown core, make it mandatory that they be watched closely. Collapse of one of these sewers would be extremely expensive and disruptive. Surveys of the brick sewer system and the compilation of a database of potential structural and service defects is now well in hand, as is the development of a cost-effective program for their replenishment.

Sewer maintenance work has been planned and staged so that it is co-ordinated with other construction work whether done by the City or by others. Since 1966, a total of $81 million has been spent on sewer maintenance activities ($2. per metre per year).

The Water Distribution System

The City distributes water for domestic consumption during peak hour demand with a range in pressure between 700 kPa and 200 kPa at street level. It also provides adequate flows for fire-fighting purposes during a time of average domestic consumption on the day of maximum demand. Potable water is purchased by the City from the Metropolitan Corporation at a number of locations within the City.

The total length of the network is approximately 1,227 km and contains over 11,000 valves, 9,000 hydrants, 123,000 service connections, 22,000 City-owned meters, and other miscellaneous appurtenances. Of the mains, 90% are older than 40 years, 30% older than 80 years, and 11.2% older than 100 years. In order to determine whether the oldest pipes have deteriorated to the extent of requiring replacement, a brief study was carried out to establish whether there is a correlation between frequency of pipe leakage and age of the pipe.

Taking into account the leakage from all causes, including corrosion, pipe settlement in fill ground, frost heave and traffic loading, we found a slight trend towards greater leakage with age. The degree of scatter in the figures, however, makes this trend far from pronounced. There appears to be no correlation between age of pipe and frequency of leakage due to the influence of corrosion alone. We have concluded that in Toronto, although some of the mains in the system are very old, there does not appear to be any reason for concern that the older mains are in need of replacement in the near future.

In 1967, a hydraulic analysis of the system showed that a program of construction of new mains was required to improve the level of service in some areas. We also reduced the number of homes affected by a shut-down of the water supply in case of maintenance work, reduced the spacing between principal mains, replaced and enlarged existing 100 mm watermains, and replaced watermains which showed signs of substantial corrosion, as well as mains which experienced frequent breakage.

Since 1968, approximately 50 km of new watermains and appurtenances have been constructed at a total net cost of approximately $15 million.

Components of Maintenance Program. The maintenance program for the existing system consists of:

- routine preventive maintenance to important appurtenances such as valves, meters, and hydrants on a regular cycle;
- ongoing leak detection surveys and repair of leaks;
- cleaning and cement mortar lining of cast-iron pipes with decreased capacity due to tuberculation;
- protection of the system from corrosion due to stray currents; and
- emergency repairs.

Hydrants normally are inspected once every 10 weeks, except during winter months when each hydrant is inspected after having been used. At that time, all hydrant barrels are drained of water to ensure that they do not freeze and become inoperable in the event of fire.

Small valves on the domestic system are operated at a maximum of 3-year intervals to ensure that they are in good working order and can be closed in an emergency. Large valves are operated annually. This program has resulted in an improvement in valve closure and will be continued.

Leak Detection Programme. Since 1968, the leak detection and repair program has covered most of the system. The value of the program has been convincing as can be seen from Table 1. The total expenditure, up to 1985, including all surveys and remedial work amounts to $1,113,349 and has resulted in a saving of water leakage amounting to 30,800 cubic metres/day, representing savings of $19,487,061. At the end of 1968, the ratio of savings to costs was about 2:1. With each passing year this ratio has increased and at the end of 1985 had risen to over 17:1.

TABLE 1. Leak Detection Survey, Costs and Savings Since 1968

LEAK DETECTION SURVEY
Costs and Savings

YEAR	COST OF SURVEY AND REMEDIAL WORK	LEAKAGE DETECTED 1,000 gal/day	ANNUAL LEAKAGE WITHOUT PROGRAMME	COST OF WATER $/1,000 gal	ANNUAL COST WITHOUT PROGRAMME	CUMULATIVE COST
1968	18,249	346	346	0.2500	31,659	31,659
1969	34,452	844	1190	0.2500	108,588	140,247
1970	36,212	335	1525	0.2500	139,156	279,403
1971	33,561	423	1948	0.2500	177,755	457,158
1972	33,261	307	2255	0.2500	206,333	663,490
1973	30,907	17	2272	0.2500	207,320	870,810
1974	46,586	569	2841	0.2500	259,241	1,130,052
1975	49,430	573	3414	0.2750	342,680	1,472,732
1976	62,910	595	4009	0.4370	641,207	2,113,939
1977	62,764	294	4303	0.5022	788,753	2,902,692
1978	53,064	181	4484	0.5909	969,259	3,871,951
1979	78,480	626	5110	0.6752	1,259,349	5,131,300
1980	83,240	281	5391	0.7685	1,516,332	6,647,632
1981	83,589	340	5731	0.8723	1,824,690	8,472,323
1982	84,809	142	5873	0.9736	2,087,053	10,559,375
1983	119,190	887	6760	1.0822	2,670,220	13,229,596
1984	91,324	24	6784	1.1988	2,976,553	16,206,149
1985	111,584		6784	1.3250	3,280,912	19,487,061
TOTALS	1,113,349					19,487,061

These figures demonstrate the value of the leak detection program and its continued implementation. In addition, the survey has provided the department with valuable information on the operation of valves, meters, and hydrants.

Rehabilitation of Cast-Iron Pipes. With the passage of time, internal growth of tubercules or nodules has occurred in the older cast-iron mains, causing a significant loss of pressure and carrying capacity. In 1968, a program of cleaning and lining these mains with cement mortar was initiated which has continued up to the present time. The rehabilitation work consists first of scraping and flushing out the debris and then applying a thin layer of cement mortar to the cleaned surface of the pipe. This protective coating inhibits further tuberculation and gives permanent protection.

Friction tests conducted before and after cleaning and lining show that the capacity has been effectively doubled and the original carrying capacity virtually restored.

Since 1968, 150 km have been scraped and lined at an average unit cost of $100. per metre. Assuming that the life of the mains which have been rehabilitated in this way is extended by 40 years, the savings in cost, amortized over a period of 40 years amounts to approximately $585,000 per year or 7% of the annual water budget.

Since 1972, work has been undertaken to protect the City's watermains from corrosion. Cathodic protection is now being installed on all pipes and service connections. In addition, the use of plastic pipe in place of ductile iron pipe is permitted.

To protect the system against corrosion caused by stray currents, the City has embarked on a program to install drainage cables from the system to sub-stations servicing the streetcar and subway systems. These improvements have reduced the stray currents in the overall system substantially and, no doubt, will reduce the rate at which metal is being lost from the watermain pipes. With the co-operation of the Toronto Hydro and the Toronto Transit Commission, the insulation of subway tracks to prevent the escape of stray currents into the ground is being undertaken.

Emergency Repairs. Watermain breaks or leaks requiring emergency repairs can occur from both joint and pipe failures. The majority of these failures occur during the winter months because frost action increases the stresses developed in the pipes. We have found that the frequency of failure is generally proportional to the severity of the winter. Pipe failures also are caused by poor pipe bedding conditions. Such conditions usually are caused by poor natural ground or disturbances to the ground by nearby construction operations.

Table 2 shows the number of leaks found and repaired over the years 1978 to 1985 for the domestic water system. The comparable figures for 1968 to 1977 also are shown. The number of leaks per kilometre compares favourably to other Metro

TABLE 2. Watermain Leaks Found and Repaired

LEAKS FOUND AND REPAIRED IN DOMESTIC WATER DISTRIBUTION SYSTEM			
YEAR	LENGTH (km)	NO. OF LEAKS	LEAKS PER KILOMETRE
1968-1977	(av) 1196.7	804	(av) 0.067
1978	1228.2	59	0.048
1979	1230.2	55	0.045
1980	1231.4	67	0.054
1981	1233.4	106	0.086
1982	1234.8	149	0.121
1983	1232.2	108	0.088
1984	1229.6	141	0.115
1985	1227.0	100	0.081

communities and is very much less than the average for watermains of comparable age elsewhere.

Streets and Sidewalks

The City of Toronto has responsibility for the maintenance of over 850 km of streets and 1725 km of sidewalks. There also are approximately 145 km of roads within the city limits under the jurisdiction of the Metropolitan Corporation. The city maintain neither those roads nor their curbs (other than to sweep them), but it does maintain the sidewalks on those roads. To further complicate matters, there are approximately 50 km of city streets containing Toronto Transit Commission streetcar track allowances for which the cty and the TTC have a shared responsibility.

In 1965, the city had a crying need for the development of a planned and staged programme for the reconstruction and rehabilitation of its pavements and sidewalks. Since no inventory of these facilities existed, first priority was given to an immediate, "on-site" evaluation of these facilities. All surface facilities were measured and visually rated in one year and the results entered into a computer file using the block as the basic module. Computer programs were developed so that the large mass of information could be manipulated. From this humble and somewhat crude beginning, the file has been progressively expanded to include a great deal of relevant data and is now the fundamental source for the department's programs.

Street Inventory File. The Streets Inventory File now contains a wide variety of details, such as the age, maintenance history, and condition rating, for each street, sidewalk, and curb in the city. A reassessment of condition rating is carried out on a 5-year cycle for typical streets and annually for streets with track allowance. Updating of maintenance and reconstruction details is carried out immediately upon completion of work in the field.

Through the use of the Streets Inventory File, it has been possible to evaluate the system and determine relative needs and qualities, pinpoint deficiences, assign priorities for the elimination of faults, and establish a maintenance system for facilities in good condition.

As pavements age, they deteriorate and their condition ratings decrease. (The higher the rating, the better the condition of the pavement.) The relation of condition rating to pavement age (the number of years since complete reconstruction) in the City of Toronto is shown in Figure 2. The level of tolerance approved by city council is Condition Rating 60 for pavements.. Therefore, as pavements get older, there is a tendency to increase maintenance activity to keep them in fair condition. Figures 3 through 6 show examples of pavements with Condition Ratings 20 through 90.

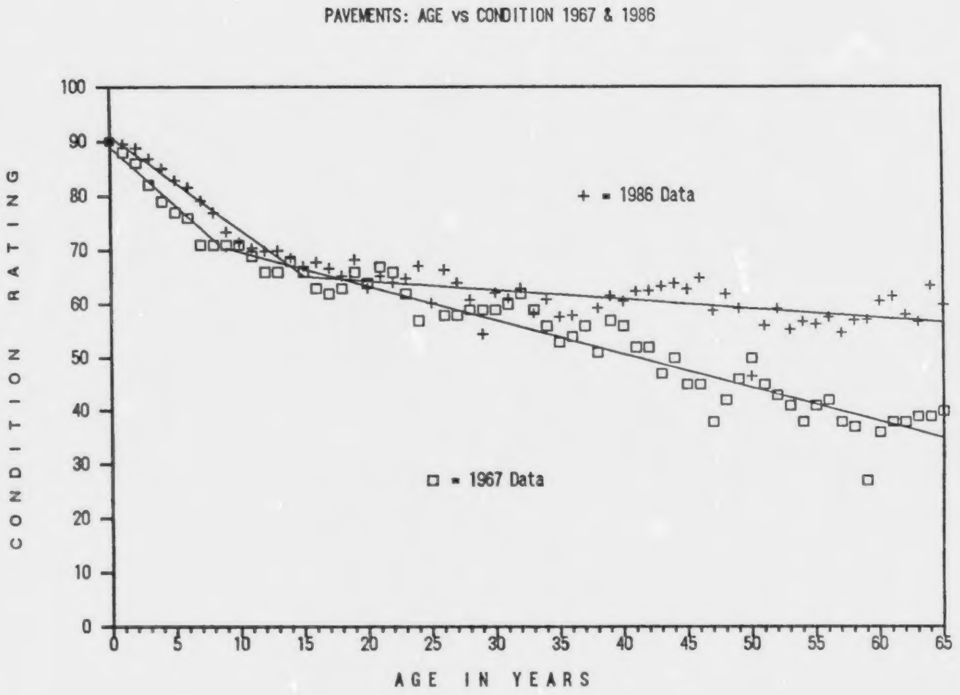

Fig. 2. Comparison of Pavement Condition Rating vs. Age for City Pavements in 1967 and 1986.

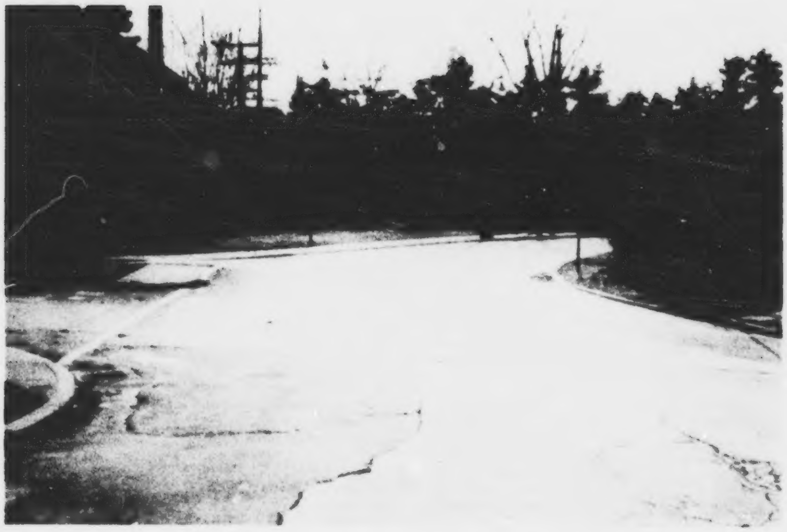

Fig. 3. Example of Pavement with Condition Rating = 20.

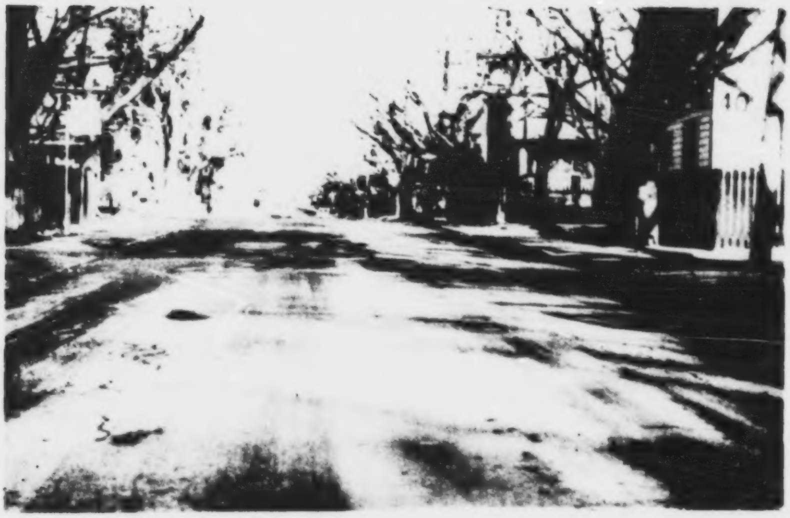

Fig. 4. Example of Pavement with Condition Rating = 40.

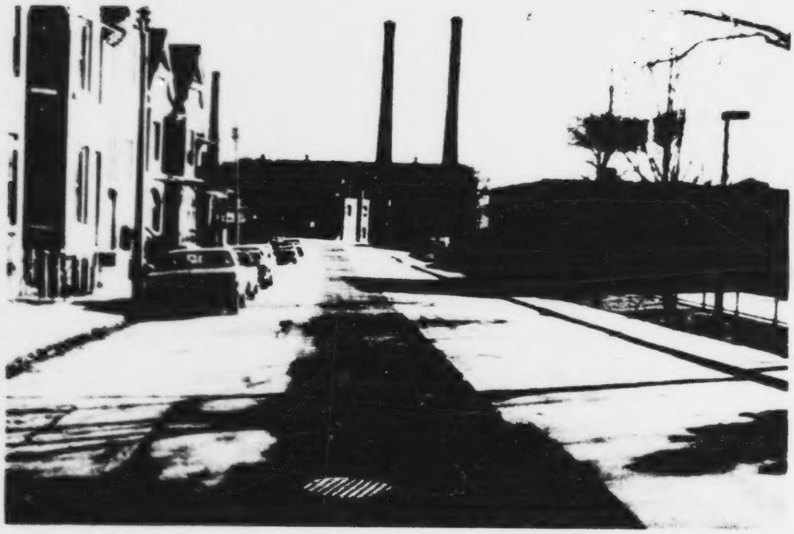

Fig. 5. Example of Pavement with Condition Rating = 60.

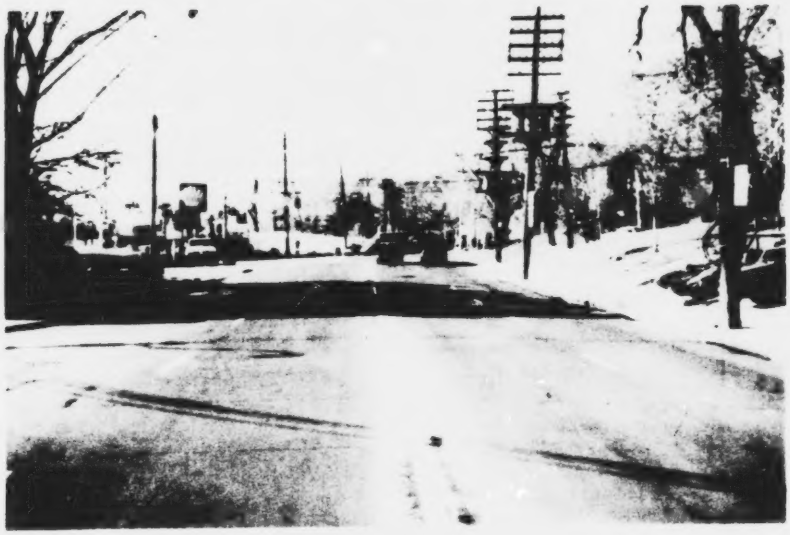

Fig. 6. Example of Pavement with Condition Rating = 90.

From experience, we realize that after a certain age (depending on the pavement's design and usage), it is more economical to reconstruct rather than to continue repairing an old or failing pavement. From analyzing the age-condition relationships and taking into account the amount of maintenance performed on the older pavements to keep them at a serviceable level, we have identified the most economical age of reconstruction for three different categories of pavements. For each of these categories there is an accompanying schedule of preventive maintenance treatments which, because of their cyclical nature, we term Maintenance Cycles. Maintenance Cycle 1 applies to local and collector streets and has a return period of 50 years. Maintenance Cycle 2 applies to arterial streets and has a return period of 45 years. Maintenance Cycle 3 applies to any street containing streetcar track allowance and has a return period of 20 years for the track allowance and 40 years for adjacent pavements. Tables 3, 4, and 5 show the approximate timing of maintenance treatments to be carried out under each Maintenance Cycle.

These ideal maintenance cycles could not be immediately applied to all pavement facilities, because their existing condition would not allow full benefit from the proposed treatments. It was decided that all pavements constructed or resurfaced since the beginning of 1952 would receive "preventive maintenance" according to the appropriate maintenance cycle, while older pavements would receive remedial maintenance to keep them hazard-free until they can be reconstructed and brought into the preventive maintenance program.

While definite cycles can be applied to pavements, the matter of sidewalks and curbs is more arbitrary. We decided, therefore, that the "as required" maintenance of these facilities would be carried out coincidental with pavement maintenance.

Methods of Pavement Repair. In Toronto, approximately 93% of the pavements are of composite construction with an asphalt surface over a concrete base. In general, reconstruction work involving composite pavement, which has 70% or more of the existing concrete base in sound condition, is carried out by base repairs and resurfacing. If less than 70% of the existing base is in sound condition, then complete reconstruction of both the base and surface is carried out. Pavements that qualify today for the reconstruction program are usually about 60-years-old with base construction that is deficient according to today's standards. Poor base construction, combined with the damage caused by cuts through the base for the installation and repair of the multitude of underground services, has led to a situation where it is rare to find a location that is suitable for base repairs and resurfacing. Therefore, almost all recent reconstruction has involved total removal of the existing pavement, concrete and all, to the subgrade level.

We hope that improved construction quality, increased durability of concrete, co-ordination of underground service construction with street reconstruction, and the

TABLE 3. Maintenance Cycle for Local and Collector Streets

MAINTENANCE CYCLE 1 - PAVEMENTS

Proposed Treatments for Local and Collector Streets
without tracks

Total in System - 5 798 000 Square Metres

Year	Type of Treatment	Cost per Square Metre	Annual Cost per Square Metre
0	RECONSTRUCTION	40.00	0.800
3	RUBBERIZED CRACKFILLING #1	0.20	0.193
10	SLURRY SEAL #1	0.95	
16	SLURRY SEAL #2	0.95	
25	ASPHALT OVERLAY INCL. COLD GRINDING	4.50	
28	RUBBERIZED CRACKFILLING #2	0.20	
32	SLURRY SEAL #3	0.95	
38	SLURRY SEAL #4	0.95	
44	SLURRY SEAL #5	0.95	
50	RESURFACE	20.00	0.400

ANNUAL COST FOR MAINTENANCE ACTIVITIES IN CYCLE 1	$0.193 - say 19 cents/m2
ANNUAL COST FOR RECONSTRUCTION PLUS MAINTENANCE ON A 50-YEAR CYCLE BASIS	$0.993 - say 99 cents/m2
ANNUAL COST FOR RESURFACING PLUS MAINTENANCE ON A 50-YEAR CYCLE BASIS	$0.593 - say 59 cents/m2

TABLE 4. Maintenance Cycle for Arterial Streets

MAINTENANCE CYCLE 2 - PAVEMENTS

Proposed Treatments for Arterial Streets
without tracks

Total In System - 1 048 300 Square Metres

Year	Type of Treatment	Cost per Square Metre	Annual Cost per Square Metre
0	RECONSTRUCTION	50.00	1.111
3	RUBBERIZED CRACKFILLING #1	0.20	0.209
18	ASPHALT OVERLAY INCL. COLD GRINDING	4.50	
21	RUBBERIZED CRACKFILLING #2	0.20	
30	ASPHALT OVERLAY WITH COLD GRINDING	4.50	
45	RESURFACE	25.00	0.556

ANNUAL COST FOR MAINTENANCE ACTIVITIES IN CYCLE 2	$0.209	- say 21 cents/m2
ANNUAL COST FOR RECONSTRUCTION PLUS MAINTENANCE ON A 45-YEAR CYCLE BASIS	$1.320	- say 132 cents/m2
ANNUAL COST FOR RESURFACING PLUS MAINTENANCE ON A 45-YEAR CYCLE BASIS	$0.765	- say 77 cents/m2

TABLE 5. Maintenance Cycle for Streets with Track Allowance

MAINTENANCE CYCLE 3 - PAVEMENTS

Proposed Treatment for Streets with Track Allowance

Track Allowance - 245,600 Square Metres
Adjacent Pavement - 430,000 Square Metres

Total in System - 675,600 Square Metres

Type of Treatment			Cost per Square Metre		Annual Cost per Square Metre
Year	Track Allowance	Adjacent Pavement	Track Allowance	Adjacent Pavement	
0	RECONSTRUCTION	RECONSTRUCTION	$80.00	$50.00	$2.250
3		RUBBERIZED CRACKFILLING		0.20	$0.260
10	REPAIR		10.00		
20	RECONSTRUCTION	ASPHALT OVERLAY INCL. COLD GRINDING	80.00	4.50	
23		RUBBERIZED CRACKFILLING		0.20	
30	REPAIR		10.00		
40	RECONSTRUCTION	RESURFACE	80.00	30.00	$1.931

ANNUAL COST FOR MAINTENANCE ACTIVITIES IN CYCLE 3	$0.260	- say 26 cents/m2
ANNUAL COST FOR RECONSTRUCTION PLUS MAINTENANCE ON A 40 - YEAR CYCLE BASIS	$2.510	- say 251 cents/m2
ANNUAL COST FOR RESURFACING PLUS MAINTENANCE ON A 40 - YEAR CYCLE BASIS	$2.181	- say 218 cents/m2

use of scheduled preventive maintenance will greatly extend the useful life of the road base. Whether resurfacing will replace total reconstruction,however, will depend to some extent on the construction industry's being able to carry out the work at a reduced cost.

The maintenance procedures used in the City are:

- Rubberized crackfilling: a preventive maintenance treatment aimed to fill and seal relatively straight-line reflected cracks in asphaltic concrete pavements. In our experience, under average conditions, 3 years following reconstruction is the most effective time to carry out this procedure. If too much time passes, moisture penetration and the resulting freeze-thaw cycles along with the pounding action of traffic will cause rapid deterioration of the pavement adjacent to the cracks. When used appropriately, it is an effective and relatively inexpensive preventive maintenance procedure.
- Slurry Sealing: a preventive maintenance treatment intended to fill and seal the numerous hairline cracks found in older pavements and to retard oxidation of the asphalt surface which can lead to ravelling and loss of aggregate. The application consists of a thin layer of a proportioned mixture of graded aggregate, asphalt emulsion, water and mineral filler, prepared on site. Slurry sealing is valuable because of the considerable benefits realized from a relatively low cost. It is easy to apply, dries fast, and there is minimal waste. Traffic can be restored after 2 to 3 hours. Maximum benefit is derived from this treatment when it is applied to a pavement which has a sound and undistorted base.
- Asphalt Overlaying: either a preventive or remedial maintenance procedure depending on the age of the pavement and the condition of the pavement base. Preventive overlaying could be thought of as a super-sealing applied to a pavement in which the asphalt surface has deteriorated to the point where slurry sealing is no longer useful, but where significant base failure has not yet occurred. This is the type of overlay intended in the maintenance cycles.

An overlay also can temporarily restore the surface of a deteriorated pavement pending complete reconstruction. Although such a pavement looks new, it will break down relatively quickly. We have found that overlaying rather than reconstructing older pavements is not a good way to save money but is nevertheless occasionally necessary to hold pavements at a hazard-free level of service.

All pavements to be overlaid are now prepared by cold-grinding which is a proven low-cost method of removing the worn surface of an asphalt pavement and the material removed can be recycled for further economy. The pavement profile can be lowered to allow the application of a uniform thickness of overlay without the loss of curb face, and little need to taper the overlay thickness next to existing track allowance and manhole covers.

The City's reconstruction and maintenance programs have been a success with average annual expenditures for maintenance and reconstruction (in today's dollars) dropping in the period from 1968 to the present by approximately 45% (Figure 7). At the current rate of reconstruction, all pavements in the City will be out of the remedial maintenance category and be receiving preventive maintenance by the year 2002 -- 15 years from now.

BUDGET APPROVALS AND SUBSIDIES

The backbone of all of our upgrading and maintenance programs since the mid-1960s has been the staging of programs over a number of years, in an order of priority, to eliminate deficiencies. City council agreed to adopt the programs and to provide funds for the necessary work in each year. All programs are reviewed and progress reports written at regular intervals to keep up with changes in technology and to ensure that the programs continue to be wanted by and are acceptable to the taxpayer.

Budget preparation has now become a matter of determining the most economical means of ordering the work and estimating the costs. It is to council's credit that, over the years, they have grasped the importance of, and been farsighted enough to commit to, carrying out the planned work rather than simply providing an estimated amount of money. With long-term programs in place, we know that the planned work and, therefore, the planned expenditures will be more or less constant in terms of today's dollars in each year. This type of resolve from council reduces the impact of unforeseen inflation and interest rate fluctuations on long-term programs.

The city also has been successful, through its long-term planning, in securing the co-operation of the Ontario Municipal Board in granting prior authorization to a portion of the capital expenditures for the forthcoming year's capital program and without awaiting the submission of the city's total capital budget request. This allows the department to put projects out to tender very early in the year when business is slow and the industry is prepared to price keenly.

Much of the road storm sewer construction, pavement and curb maintenance, and reconstruction is eligible for subsidy under the Public Transportation and Highways Improvement Act to the amount of 50 cents on every dollar. However, there is a ceiling on the allocation approved each year which, in terms of constant dollars, is falling further and further behind the amount of subsidy requested (Figure 8). Since 1971, the Toronto taxpayer's share of expenditure for eligible work done has risen from the mooted 50% to more than 70% as shown in Figure 9. The Province of Ontario has been asked repeatedly to review and correct this funding inequity; we have high hopes that they will.

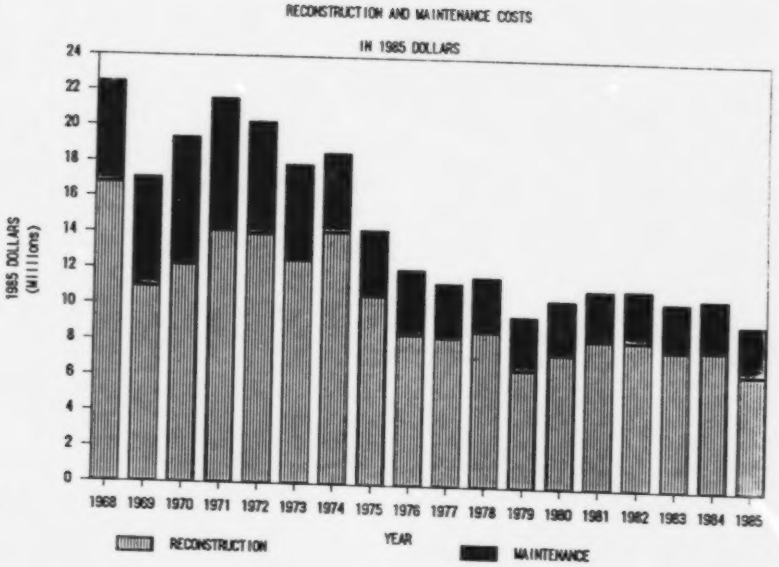

Fig. 7. Pavement and Sidewalk Reconstruction and Maintenance Costs since 1968 expressed in 1985 Dollars.

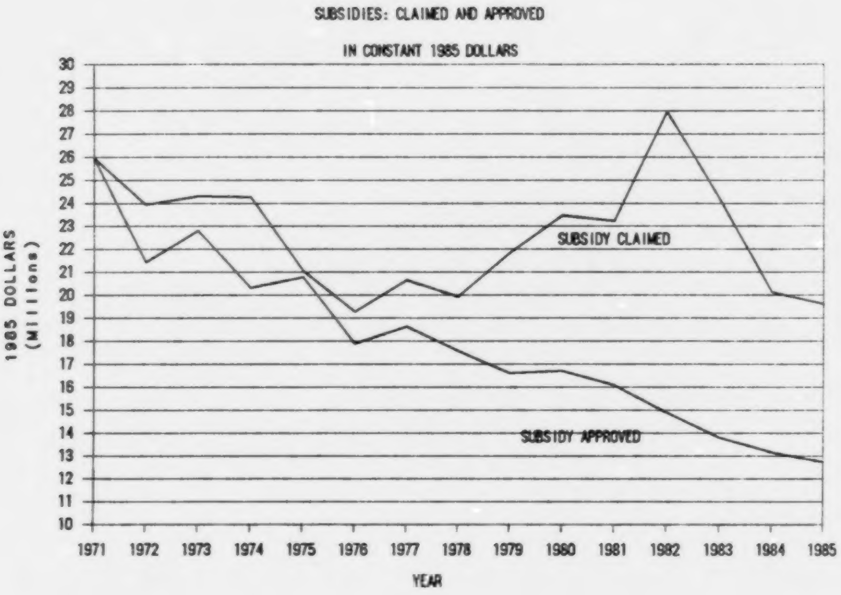

Fig. 8. Comparison of Subsidies Claimed and Approved Under the Public Transportation and Highways Improvement Act since 1971 expressed in 1985 Dollars.

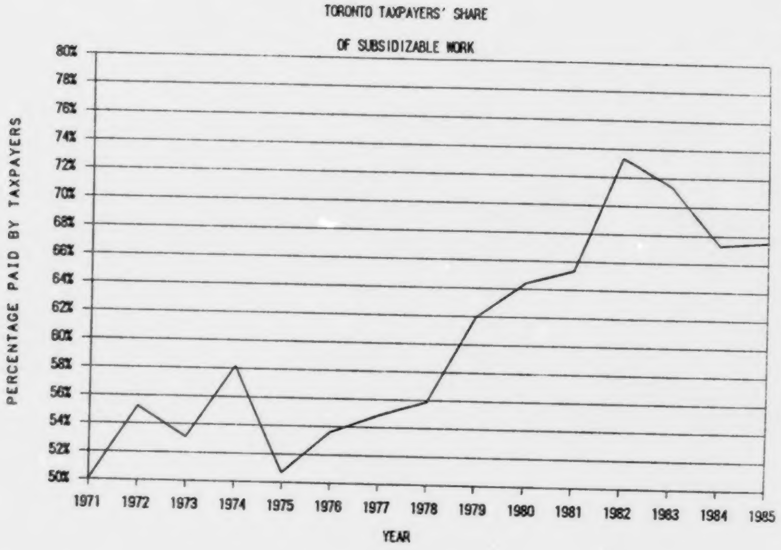

Fig. 9. Toronto Taxpayers' Share of the Cost of Work Eligible for Subsidy since 1971.

CONCLUSIONS

The upkeep and life extension of municipal infrastructure inwhich tax-payers have invested more than $2 billion is a top priority for the City of Toronto. The following guidelines have been developed and accepted as "basic ingredients" of a sound process:

- compile a basic inventory of your system;
- determine the extent, nature and location of the deficiencies;
- keep economics uppermost in mind and set practical levels of service. (Remember that it is the taxpayer who ultimately foots the bill.);
- establish staged programs to eliminate deficiencies systematically and in an order of priority;
- put together programs of preventive maintenance for those facilities which are not deficient;
- ensure that the plan is politically palatable and capable of sustained support;
- stage the program over a period of years and make sure the public knows about the plan;
- co-ordinate your program with those of others, i.e., do not reconstruct a road and 2 years later dig it up for underground construction;
- review and report on your program at regular intervals to ensure that you are keeping up with changes in technology;
- make the construction industry in your area aware of your program. Contractors will be more efficient and competitive when they know that you have a planned program that can provide them with work for a number of years.

The City of Toronto is well on top of the work of rehabilitation and upkeep of its municipal infrastructure. The programs developed for the water distribution system, the sewer system, roads, sidewalks, bridges and underpasses have been tenaciously implemented owing, in large part, to the fact that we have worked assiduously to develop long-term plans founded on simple guidelines.

REHABILITATION OF MUNICIPAL SERVICES IN QUEBEC COMMUNITIES: THE LAVAL EXPERIENCE

Claude Asselin
and
André Perrault
City of Laval, Quebec

ABSTRACT

The Province of Quebec's "Water Purification Program", which makes funds available for the construction and upgrading of sewage collection and treatment facilities, led the City of Laval to evaluate, analyze and measure the influence of infiltration and inflow on its sewer system. Three aspects of Laval's rehabilitation program are examined:

- the reduction of inflow on a combined sewer through a system of "dual drainage";
- grouting to reduce infiltration under the difficult conditions of a high water table;
- the elimination of inflow surfaces, the correction of storm, combined and separated sewers that are cross-connected, and the reduction of infiltration to reduce overflows of untreated wastewater.

These types of activities must continue in order to meet the goal of reducing water pollution. Particular attention should be paid well to the aging of underground services. Laval's water distribution system and filtration plants are also undergoing rehabilitation.

RÉSUMÉ

La mise en oeuvre du programme d'assainissement des eaux du Québec a favorisé la réhabilitation des réseaux d'égouts de Ville de Laval. À l'aide de ce programme, Ville de Laval a analysé le comportement de son réseau et mesuré l'impact des eaux parasites transportées par infiltration et captage. Trois (3) exemples d'intervention sur le réseau d'égouts sont décrits:

a) la réduction de l'apport des eaux de ruissellement dans un réseau unitaire en applicant les principes du "dual drainage."
b) La réduction des eaux d'infiltration dans des conditions difficiles dues à des hauteurs de nappes phréatiques élevées en utilisant les techniques de colmatage par injection sous pression de gel acrylamide.
c) L'élimination de superficies de captage, de décroissement de type de réseau ainsi que la réduction des débits d'infiltration, permettant de réduire les débordements d'eaux usées sans traitement.

Ce type d'intervention devra se poursuivre afin de rencontrer les objectifs d'assainissement. De plus, une attention particulière devra être apportée au vieillissement des services souterrains. Le réseau d'aqueduc et les usines de filtration font aussi l'objet de travaux de réhabilitation. À cet égard, plusieurs millions de dollars seront investis au cours des prochaines années.

REHABILITATION OF MUNICIPAL SERVICES IN EDMONTON

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Edmonton, Alberta

ABSTRACT

Events leading up to the current status of Edmonton's infrastructure, including its roads, bridges, sewer and water systems, are described in this paper. Recently-initiated rehabilitation programs, such as those dealing with roadway reconstruction, structure review and the cast iron replacement surcharge, are examined. Also presented is the Alberta Municipal Partnership in Local Employment Program (AMPLE).

RÉSUMÉ

L'exposé décrit les événements qui ont mené à l'état actuel de l'infrastructure d'Edmonton, ponts et chaussées, réseaux d'aqueduc et d'égout y compris. MM. David et Smith examinent également les programmes de réaménagement entrepris dernièrement, notamment ceux qui concernent la reconstruction des chaussées, l'examen des structures et la surcharge assortie au remplacement de canalisations en fonte. Ils abordent enfin la participation des municipalités albertaines au programme d'emploi local du gouvernement de la province.

The City of Edmonton, although a relatively young city, has its share of civil infrastructure shortcomings. In the FCM survey of 1983, these were estimated to require $2 billion to repair.

Edmonton's situation has arisen from two basic factors:

1. the use of rigid base roads that was our practice from 1950 through to 1969, an era that covered the city's major growth years when its population grew from 140,000 to 500,000 (Figure 1); and
2. the use of cast-iron watermains in roughly the same time period.

The combination of our soil type, which is a swelling clay, inferior metals of the day, and insufficient attention to infrastructure maintenance has resulted in watermain breaks at a rate of 30 per day on a cold winter day (1600 in 1985) and road surface cracking and potholes due to reflective cracking of the road base.

We must address these and such other major problems as subsidence of the road bed, districts with combined sewers, crumbling wood and masonry sewers, and bridge structures subject to rusting, salt action, and concrete creep.

ROADWAY SYSTEM

Our first paved roads were constructed in the early 1900s. Since then, construction methods have varied with the technology of the day. Until 1960, residential streets were constructed with a water-bound base and an asphalt surface. The arterial and collector roadway system, carrying larger volumes of traffic and heavier loads, was constructed with a rigid concrete base and an asphalt running surface. Since 1969, soil cement and full-depth asphalt sections have been used.

Due to recognition of the road deterioration problem and a change in provincial guidelines for the use of grant dollars, we have been able to increase our resurfacing efforts during the past 2 years without increasing the tax base (Figure 2). This increase, applied to arterial and collector roadways, has given us a highway resurfacing program of 10 kilometres per year on an inventory of 100 kilometres. We are scheduling 35 kilometres per year of arterial and collector resurfacing, which will give us a 17.5- year cycle, which is somewhat short of our desired 61 kilometre per year for a 10-year cycle (based on 610 kilometre inventory).

Our major concern is the shortfall in our residential roadway resurfacing program. Here we are encountering a demand for resurfacing, but a refusal to pay for local improvements. Hence our program is 19.3 kilometres per year resulting in a 93-year cycle on our 1797 kilometres of residential streets. We would like to increase this effort to 90 kilometres per year, but doubt that the funding will be available.

FIG 1

CITY OF EDMONTON

POPULATION

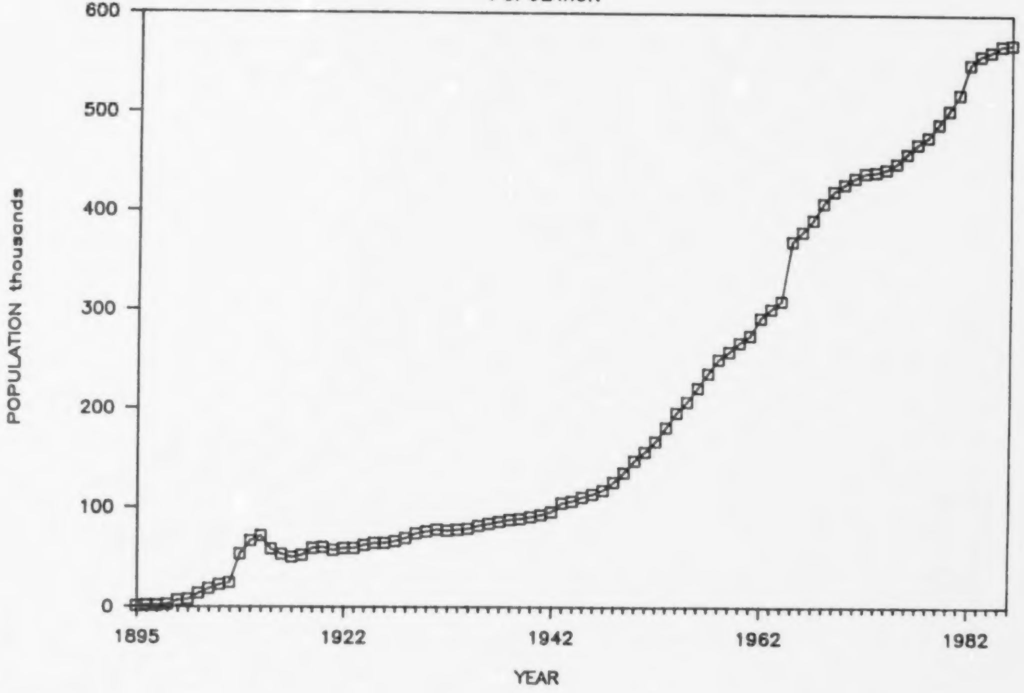
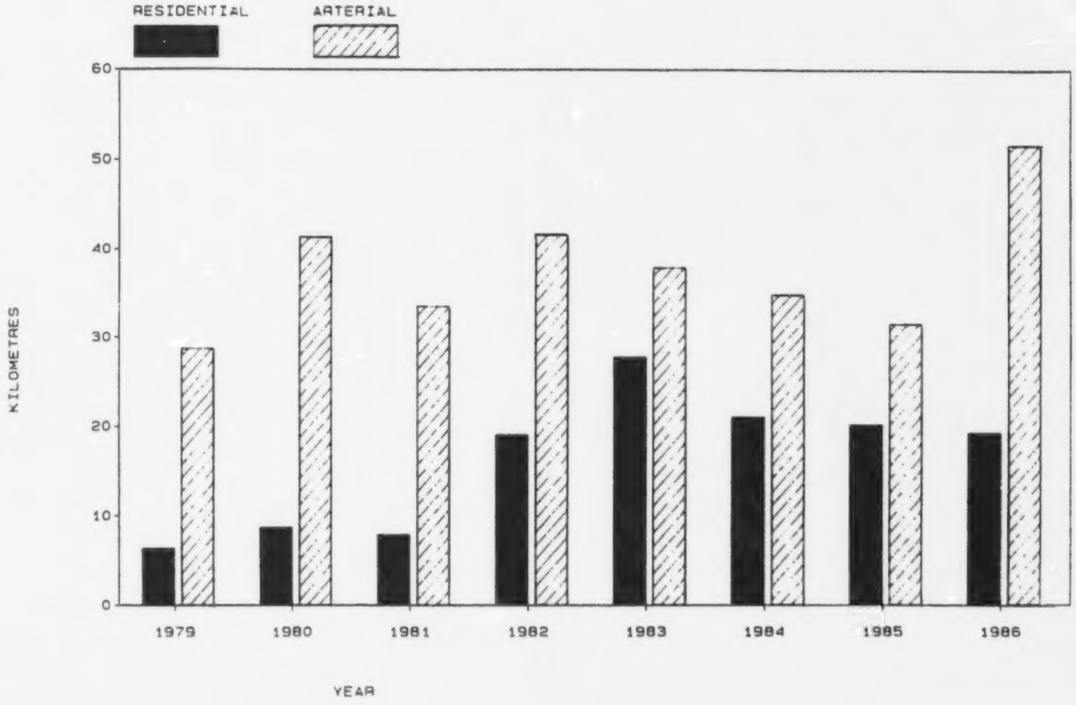


FIG 2

ROADWAY RESURFACING LENGTH



In addition to the resurfacing program, we are carrying out:

Activity	Amt. of Material/km	Annual Costs
Pothole repairs	1.20 tonnes/kilometre	$1,302,000
Lane patching	2.44 tonnes/kilometre	$ 169,000
Patch paving	5.18 tonnes/kilometre	$1,205,000
Crack sealing	12.7 lin.m./kilometre	$ 342,000
	TOTAL	$3,000,000

In total the paved-road maintenance budget in 1986 was $9,186,000.

It is our goal to get 50 years of life or more out of arterial and collector roadways and residential roads. That means they would last virtually the life of the community they were constructed to serve.

Due to our fast growth rate, most of our capital construction dollars were going for the provision of new facilities. With the decrease in growth rate, we have been allocating more of our program to reconstruction; and in 1987, 70% of our $95 million capital works will go towards reconstruction of existing facilities (Figure 3).

SIDEWALK, CURB & GUTTERS

We attempt to replace all curb and gutter and sidewalk in the city with local improvement funding. There are, of course, objections to this funding method. Our replacement program in 1986 was 11,833 lineal metres of curb and gutter and 4,980 lineal metres of sidewalk. This level of replacement has been relatively stable for the past decade (Figure 4).

In addition to the replacement of concrete appurtenances, the Concrete Maintenance Program for 1986 was $2 million, the major components of which were:

Activity Measure/km		Annual Costs
Sidewalk repair	1.95 square metres	$ 696,000
Curb & gutter repair	0.89 lineal metres	$ 443,000
Asphalt walk overlay	9.20 square metres	$ 176,000
	TOTAL	$1,315,000

FIG 3

ARTERIALS / EXPRESSWAYS - CAPITAL CONSTRUCTION

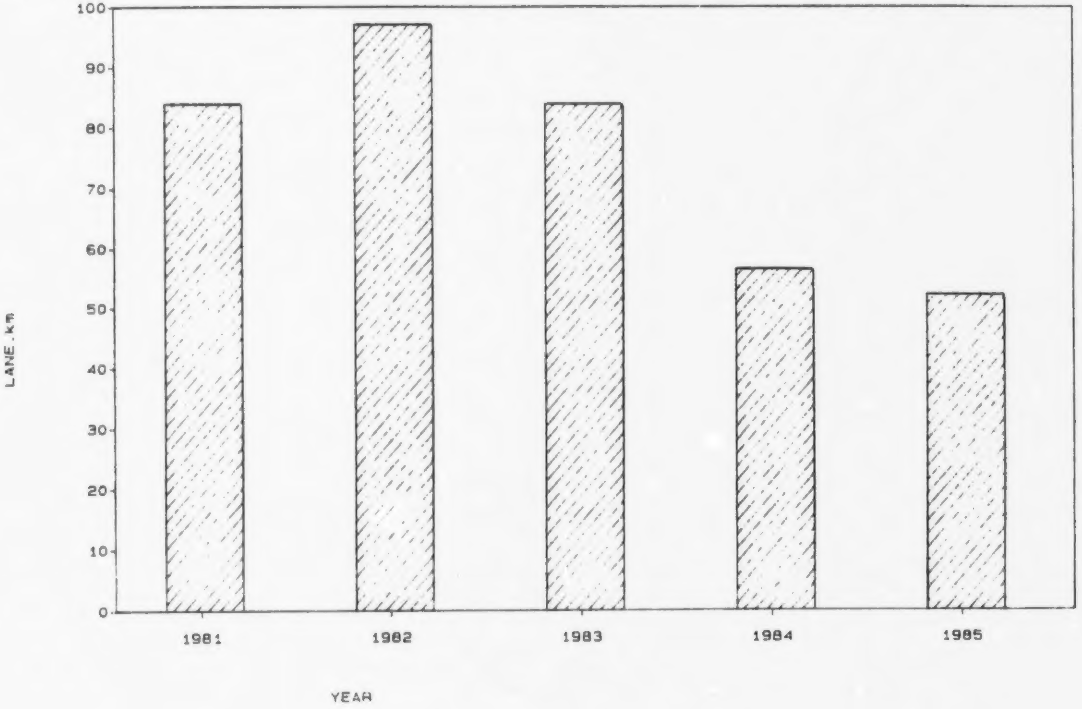
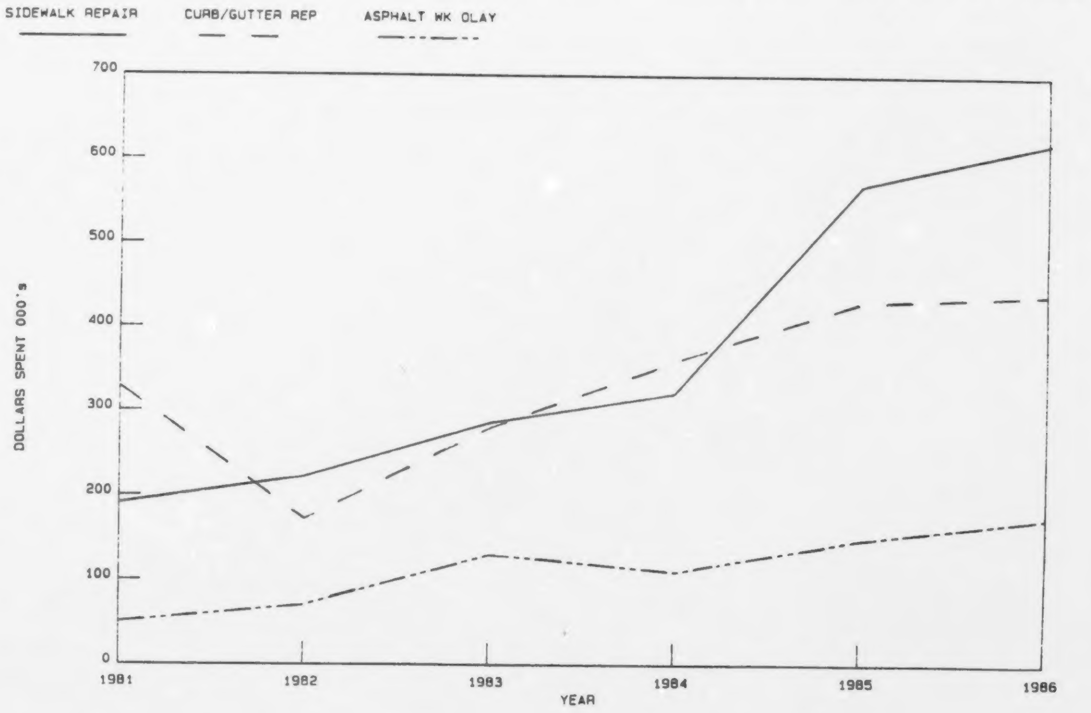


FIG 4

CONCRETE PROGRAM . . . . . .MAJOR ACTIVITIES



BRIDGES

Our inventory of bridge structures consists of 11 cross-river bridges and 81 over- or underpasses. There are also 20 rail structures, for some of which we share responsibility. During the past 6 years, the bridge maintenance program has remained constant between $1.1 million and $1.2 million per year (Figure 5). This figure represents approximately one-third of the desired level of maintenance funding. In addition to the routine repairs in the past decade, two cross-river structures have had decks replaced, one through-truss structure was widened and one cross-river structure was replaced.

WATER SYSTEM

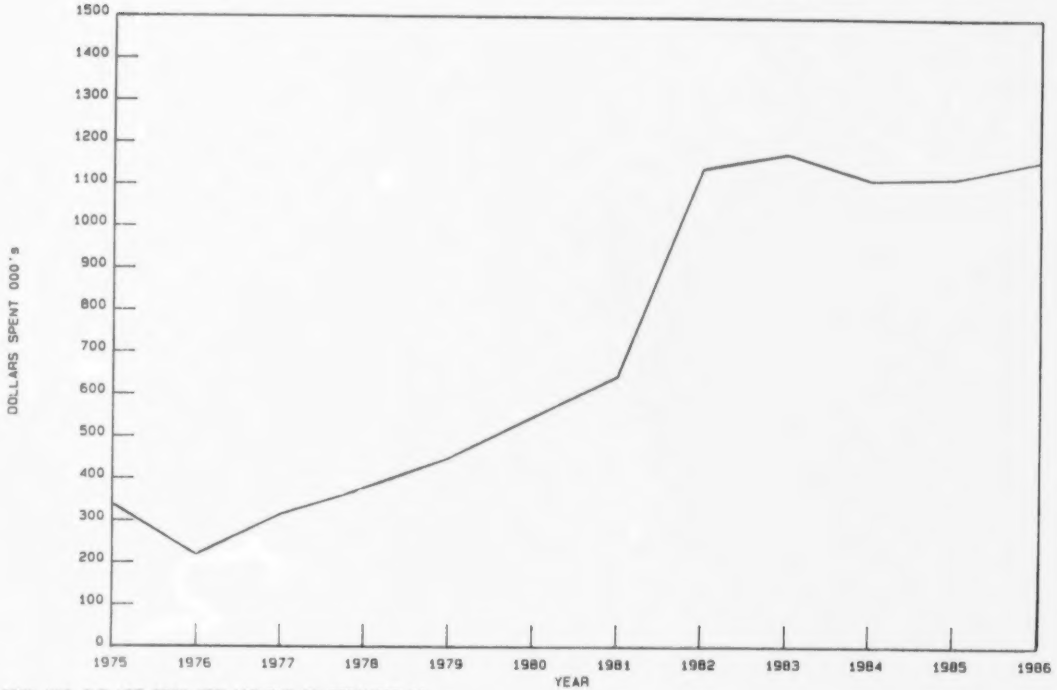
The first piped water distribution system in Edmonton was constructed in 1902 and 1903 -- 10 kilometres of cast-iron pipes and 55 hydrants. The length of the system today is 2500 kilometres. Many materials have been used for the pipes: almost half of the system is cast-iron pipe; asbestos cement, steel, concrete, plastics, wood, and copper have also been used. The pipes are buried two or three metres deep. The most serious problem in our distribution system is the rapidly increasing frequency of breaks and leaks in the cast-iron pipes. Figure 6 shows the areas affected. Figure 7 shows how the number of such breaks has increased from approximately 52 in 1951, to over 1600 in 1985. Notice that the length of cast-iron mains has remained almost the same since 1964. The 150-mm pipes constitute 55% of our system (Figure 8), and have the highest frequency of breaks (Figure 9). Pipes other than those made of cast-iron comprised 100 kilometres in 1951 and 1500 kilometres today, but the number of breaks has remained steady at around 50 each year (Figure 10).

The result of our experience has been a substantial increase in our replacement program (Figure 11). Last year, 21 kilometres of cast-iron mains were replaced with P.V.C. pipes.

Whereas new water mains are paid for by the growth of the city, either from developer's contributions, local improvement taxes, or the increased revenues from water sales, the replacement of existing mains is imposing an increasing cost on a static population and economy. At an average cost of $350 per metre, last year's replacement program cost over $7 million, 10% of the water utility's revenues. At the same time, there are demands for large expenditures to increase the quality of the drinking water and to improve the level of service in all other facets of the water operation.

FIG 5

BRIDGE MAINTENANCE FUNDING



DOES NOT INCLUDE DECK REPLACEMENT OR RECONSTRUCT

FIG 6

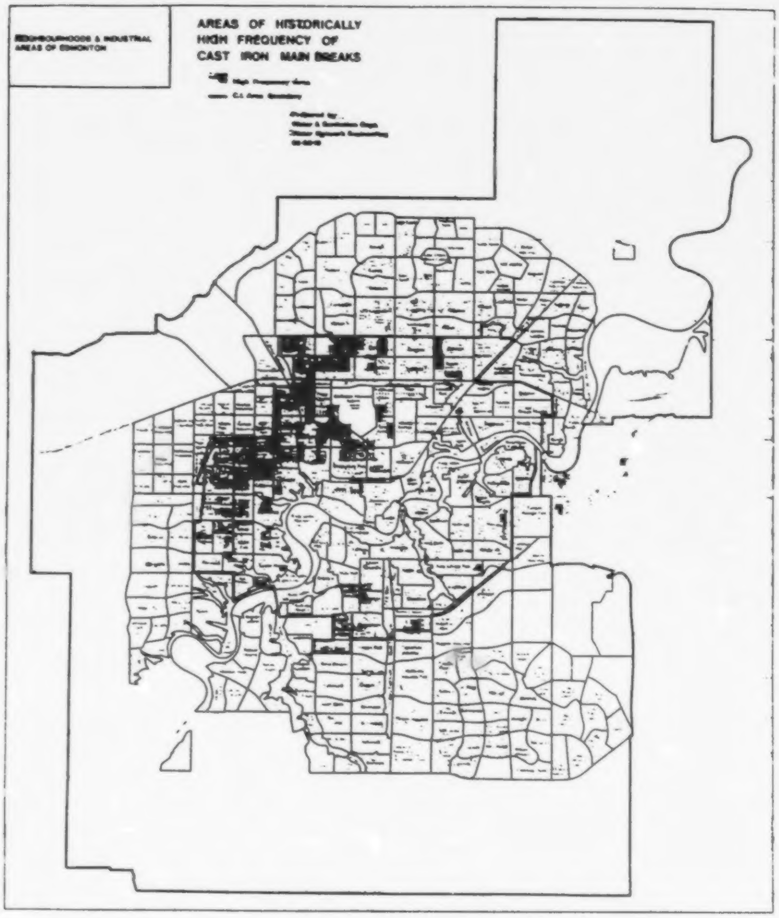

NEIGHBOURHOODS & INDUSTRIAL AREAS OF EDMONTON
AREAS OF HISTORICALLY HIGH FREQUENCY OF CAST IRON MAIN BREAKS
High Frequency Area
C.I. Area Boundary
Prepared by ...

FIG 7

LENGTH & BREAKS
Cast-Iron Water Mains

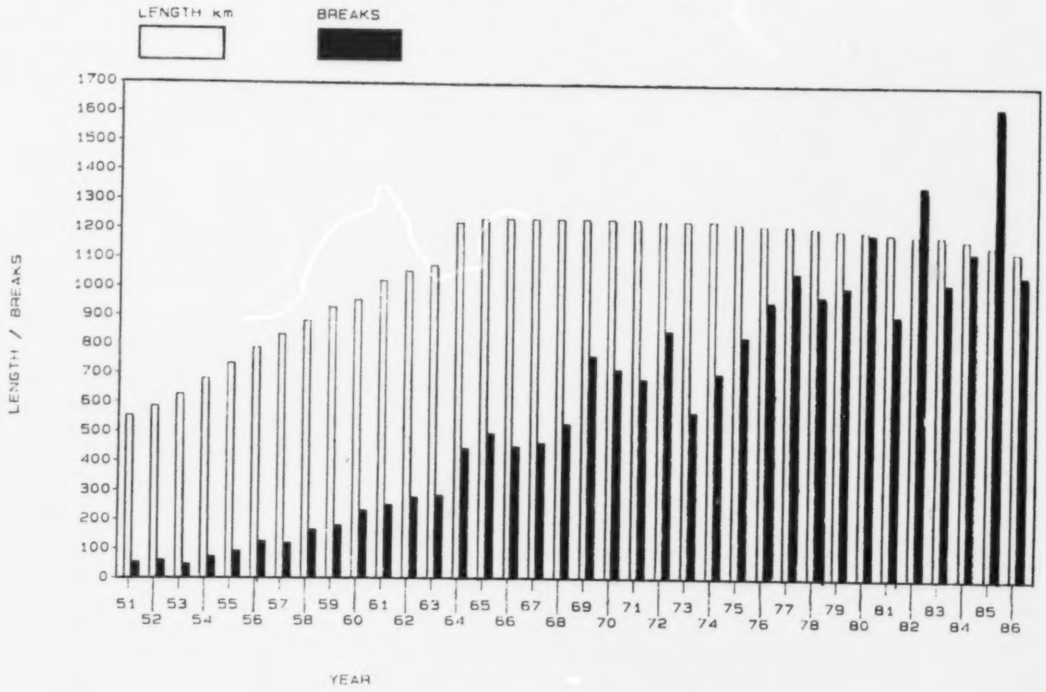


FIG 8

LENGTH OF CAST IRON PIPE BY SIZE

CAST IRON WATER MAINS

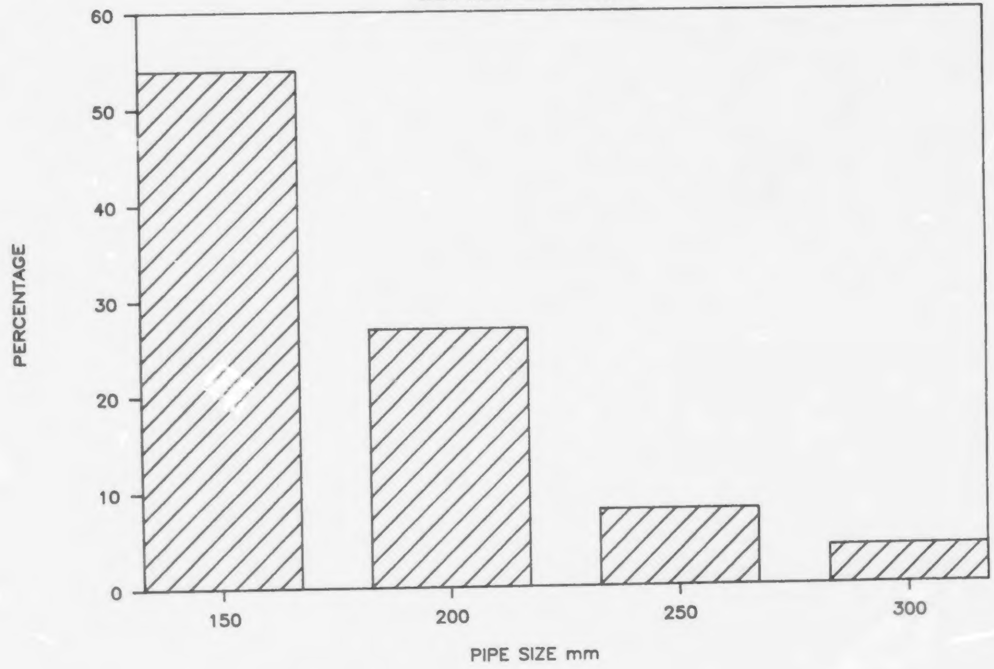


FIG 9

BREAKS PER KILOMETRE (1983)

CAST IRON WATER MAINS

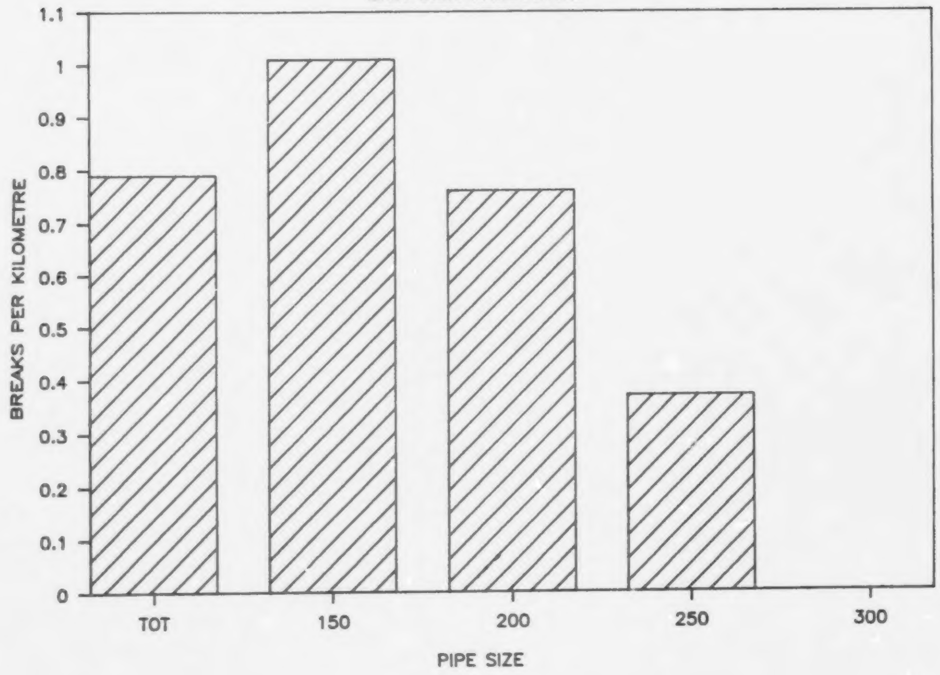


FIG 10

BREAKS OTHER THAN CAST–IRON WATER MAINS

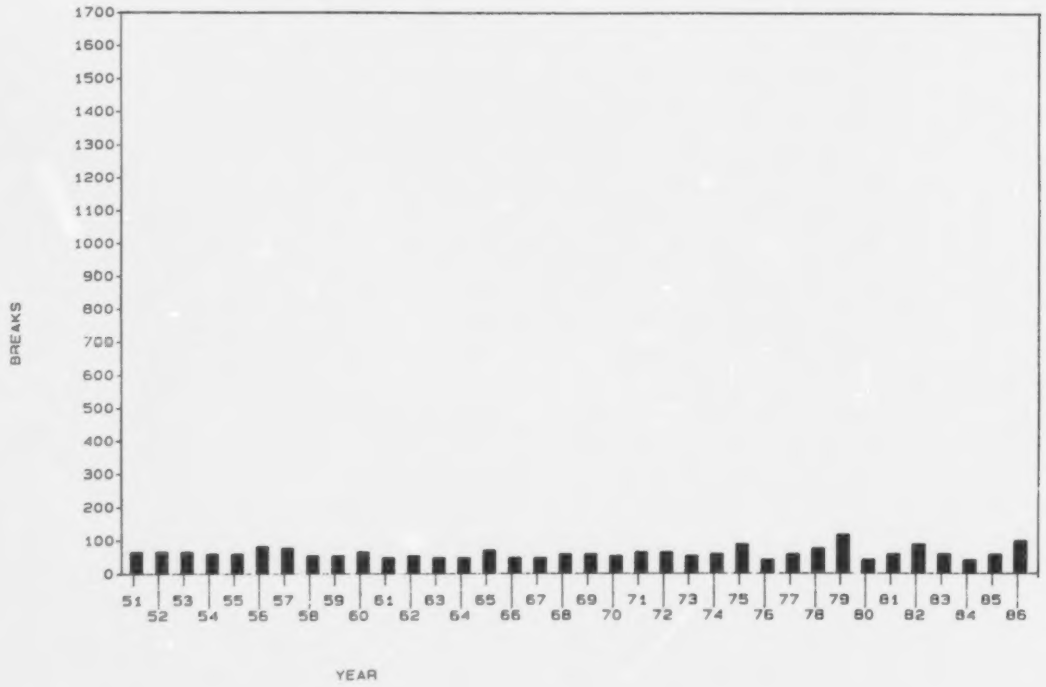
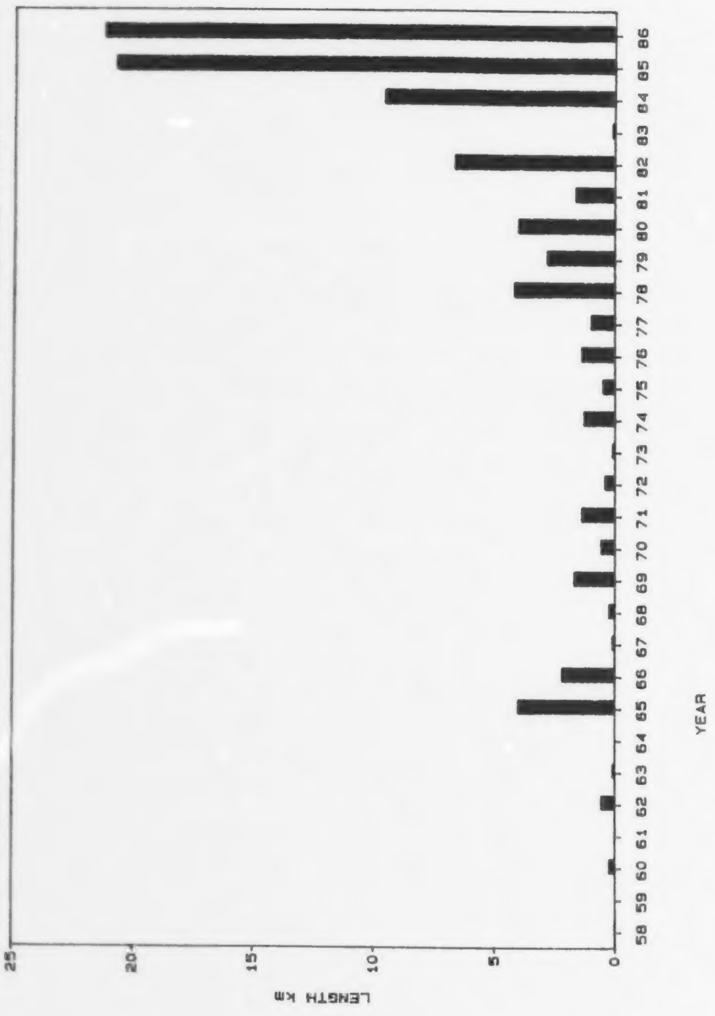


FIG 11

LENGTH OF WATER MAIN REPLACEMENTS



Operational costs and debt-servicing are met entirely from water sales revenues. All customers pay on a metered rate and the average domestic water bill is $18 per month (Figure 12). A separate fund for cast-iron watermain replacement was established in 1986, and the charges are billed separately on the monthly utility bills. This will be presented in more detail later.

SEWER SYSTEM

The sewer system in Edmonton can be divided into two areas, the older, combined sewers area and the newer, separated area (Figure 13). In the separated area most of the storm water is directed to the river and only sanitary sewage is treated at the Gold Bar Wastewater Treatment Plant. In the combined area all flows except some surcharges are treated. Figure 14 shows the length of the sewer system in Edmonton since 1960.

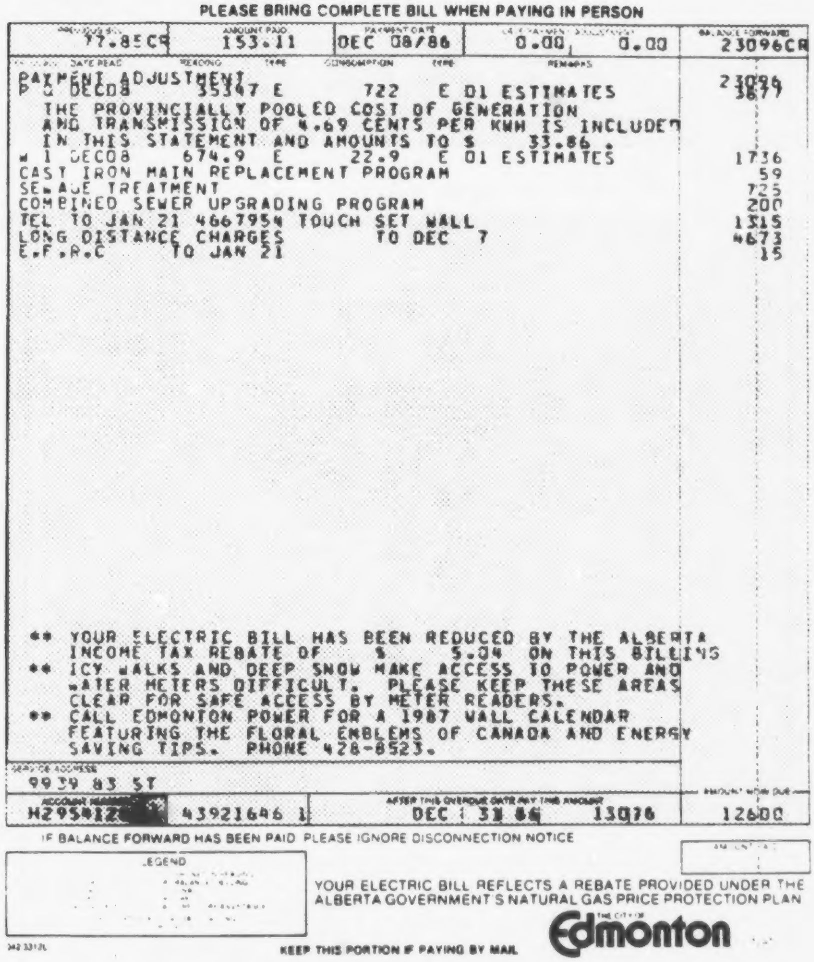
The condition of the sewer system is known through sample televising, customer complaints, and maintenance records, but the physical condition is less well known than that of the watermains. It has been difficult to justify extensive condition surveys when the sewers perform adequately most the time. Edmonton is concerned, however, that as the pipes age, the time approaches when replacement will be required at a rate similar to the original construction rate.

A second problem developing over time with the sewer system is that the level of service desired by our customers is higher than it was when the sewers were originally designed and constructed. It is less acceptable now to permit the occasional overflow during heavy rainfall to discharge into the river, especially upstream of the water treatment plant at Rossdale. It is also less acceptable to flood basements, especially in newer homes where expensive basement development is more common than it was 20 or 30 years ago. In recent years there have been several flooding incidents in new subdivisions, in older areas, and along the river, and citizens have demanded that the city minimize the risk of flooding.

TREATMENT PLANTS

Edmonton has two water treatment plants and one wastewater treatment plant. The Rossdale Water Treatment Plant is located in the centre of the city and was built in 1947 to replace older facilities on the same site. Because of the age of this plant, changes in water treatment technology, and standards since 1947, it is undergoing extensive refurbishment at a cost of $50 million. It is to be completed in 1989. Its capacity will remain unchanged.

FIG 12



PLEASE BRING COMPLETE BILL WHEN PAYING IN PERSON

PREVIOUS BILL	AMOUNT PAID	PAYMENT DATE	[illegible]	BALANCE FORWARD
77.85CR	153.11	DEC 08/86	0.00 0.00	23096CR

```
      DATE READ   READING    TYPE   CONSUMPTION   TYPE        REMARKS
PAYMENT ADJUSTMENT                                                          23096
P Q DEC08      35347 E          722    E 01 ESTIMATES                        3677
  THE PROVINCIALLY POOLED COST OF GENERATION
  AND TRANSMISSION OF 4.69 CENTS PER KWH IS INCLUDED
  IN THIS STATEMENT AND AMOUNTS TO $     33.86 .
W 1 DEC08      674.9  E        22.9    E 01 ESTIMATES                        1736
CAST IRON MAIN REPLACEMENT PROGRAM                                             59
SEWAGE TREATMENT                                                              725
COMBINED SEWER UPGRADING PROGRAM                                              200
TEL TO JAN 21 4667954 TOUCH SET WALL                                         1315
LONG DISTANCE CHARGES          TO DEC  7                                     4673
E.F.R.C       TO JAN 21                                                        15

**  YOUR ELECTRIC BILL HAS BEEN REDUCED BY THE ALBERTA
    INCOME TAX REBATE OF      $      5.04  ON THIS BILLING
**  ICY WALKS AND DEEP SNOW MAKE ACCESS TO POWER AND
    WATER METERS DIFFICULT.  PLEASE KEEP THESE AREAS
    CLEAR FOR SAFE ACCESS BY METER READERS.
**  CALL EDMONTON POWER FOR A 1987 WALL CALENDAR
    FEATURING THE FLORAL EMBLEMS OF CANADA AND ENERGY
    SAVING TIPS.  PHONE 428-8523.
```

SERVICE ADDRESS
9939 83 ST

ACCOUNT NUMBER		AFTER THIS OVERDUE DATE PAY THIS AMOUNT		AMOUNT NOW DUE
H2954I2[redacted]	43921646 1	DEC 31 86	13076	12600

IF BALANCE FORWARD HAS BEEN PAID PLEASE IGNORE DISCONNECTION NOTICE

LEGEND

AMOUNT PAID

YOUR ELECTRIC BILL REFLECTS A REBATE PROVIDED UNDER THE ALBERTA GOVERNMENT'S NATURAL GAS PRICE PROTECTION PLAN

THE CITY OF Edmonton

342 3312L

KEEP THIS PORTION IF PAYING BY MAIL

FIG 13

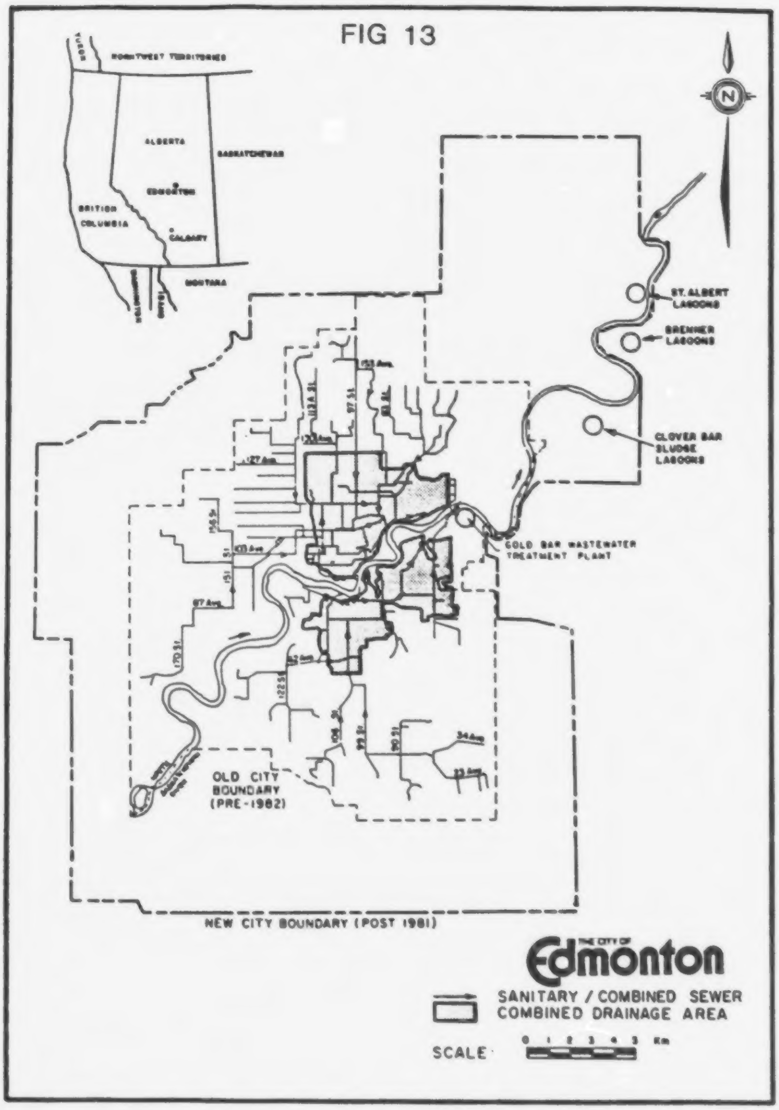
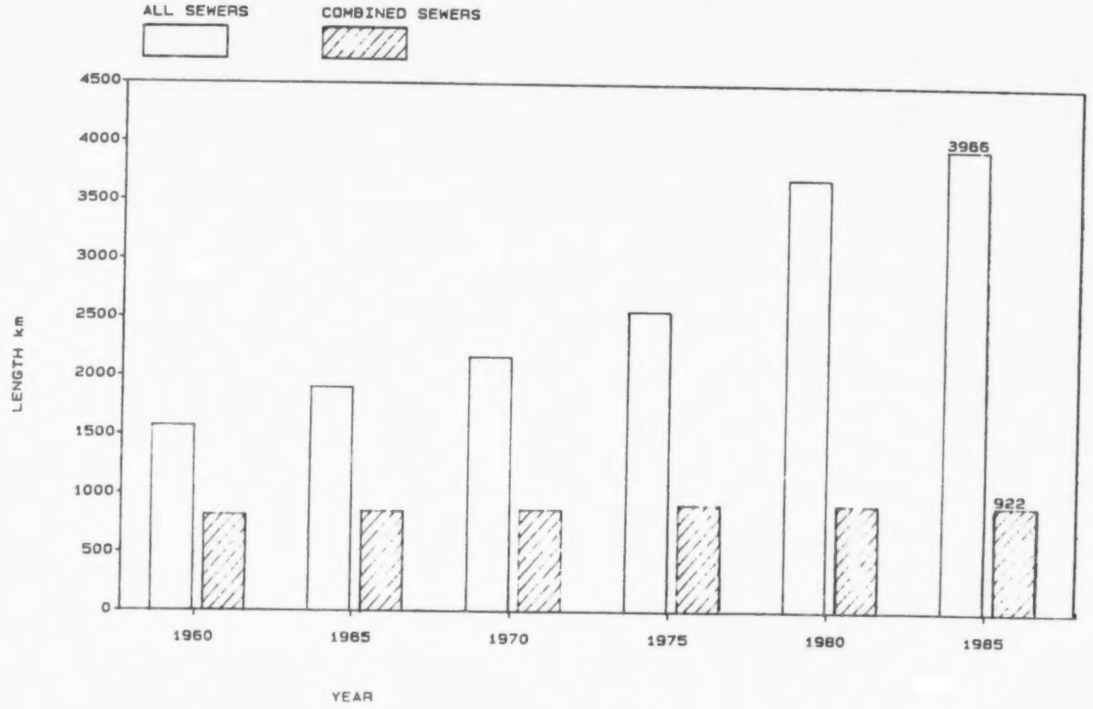

YUKON
NORTHWEST TERRITORIES
ALBERTA
SASKATCHEWAN
EDMONTON
BRITISH COLUMBIA
CALGARY
MONTANA
N
ST. ALBERT LAGOONS
BRENNER LAGOONS
CLOVER BAR SLUDGE LAGOONS
GOLD BAR WASTEWATER TREATMENT PLANT
OLD CITY BOUNDARY (PRE-1982)
NEW CITY BOUNDARY (POST 1981)
THE CITY OF Edmonton
SANITARY / COMBINED SEWER
COMBINED DRAINAGE AREA
SCALE 0 1 2 3 4 5 Km

FIG 14

LENGTH OF SEWER SYSTEM



The E.L. Smith Plant was built in 1975 on a new site upstream near the river close to the city's western limits. Most of the capital investment in this plant so far has been used to increase capacity and reliability for supply to Edmonton and subdivision communities.

Wastewater from all combined and sanitary sewers is treated at the Gold Bar Plant. This plant was built in 1956 and has been expanded several times over the years, most recently in 1977, to continue to meet provincial regulatory requirements for effluent discharges.

INNOVATIVE FUNDING

Edmonton has initiated a number of innovative funding methods including:

- 1986 pothole-resurfacing program;
- cast-iron water main replacement program;
- combined-sewer upgrading program;
- Mill Woods sewer relief program; and
- Alberta Municipal Partnership in Local Employment (AMPLE).

Pothole-Resurfacing

In 1986, a $1 million surplus in the snow removal budget was allocated to the street infrastructure. The $1 million dollars for roadway rehabilitation was divided between resurfacing and roadbase repair.

Resurfacing work was completed at ten locations at a cost of $573,000. This work included surface milling ($146,000), resurfacing ($354,000), and line marking ($73,000). Line marking costing about $11,000 remains to be completed, and due to inclement weather conditions, this work will probably have to be undertaken in 1987.

Road base repair was completed at 73 locations at a cost of $382,592. In the order of $37,408 worth of work allocated to roadbase repair was not completed, again because of severe winter conditions beginning November 7, 1986. The remaining locations will be scheduled as part of the 1987 work program.

Cast-Iron Water Main Replacement Program

Edmonton's policy has been to fund the water and sanitary sewer systems from customers rather than from general taxes. This principle is being continued in the replacement and rehabilitation of older systems.

To replace most of the cast-iron water mains, a 55-year time frame at 20 kilometres per year was established 2 years ago. To fund this cost of approximately $7 million every year, and to reduce the city's reliance on long-term debt, a program financed from current revenues was developed. It is identified as a surcharge on each customer's water bill. The surcharge, set at 3.42% of the monthly water bill in 1986, raised $1.8 million. In 1987, the surcharge will be 6.84% of the monthly water bill and will raise $3.9 million. By 1989, the surcharge is expected to cover all of the costs of the replacement program. The surcharge and water rates are set annually by city council.

Combined-Sewer Upgrading Program

In 1978, Edmonton embarked on a 20-year program to upgrade the combined sewer system's hydraulic capacity through a special levy on redevelopment in the combined-sewer area. Using this levy caused problems of equity and the revenues declined owing to decreased construction activity.

In 1986, therefore, Edmonton changed the program to a 15-year, $67 million program funded entirely from a surcharge on each customer's monthly sewer bill. Residential customers pay a flat rate of $2 per month and non-residential customers up to $25 per month. All customers in the city, whether in combined or separated sewer areas, pay this surcharge.

Mill Woods Sewer Relief Program

This program, to relieve local flooding in Mill Woods (southeast Edmonton), is a 3-year program also funded by a surcharge on all city customers at the rate of $1.80 per month for 1987 to 1989. Approximately $11 million will be raised to pay for new storm sewers and storage lakes. This program is indicative of a new trend to fund storm sewers from utility rates, rather than property taxes.

Alberta Municipal Partnership in Local Employment Program (AMPLE)

This initiative by the Province of Alberta will provide grants directly to municipalities for employment creation. The Ciry of Edmonton has combined this opportunity with the need for infrastructure replacement and will spend the first $30 million grant over 3 years in three neighbourhoods. The watermains, sewers, and roadways will be extensively reconstructed, creating approximately 1000 jobs in the private sector. Construction will start during 1987.

CONCLUSIONS

We are not keeping pace with the deterioration of our urban infrastructure. We currently are able to provide desirable rehabilitation only to the primary highway system and those roadways requiring reconstruction to accommodate increasing and changing traffic volumes. Our watermain rehabilitation program is being expanded in a "no-growth" economy, consuming an increasing proportion of water revenues. The condition of our aging sewers is deteriorating at an unknown rate. An overall assessment of the infrastructure indicates the pressing need to increase our rehabilitation efforts. This can be accomplished only by improving our pavement management programs and water and sewer condition assessment, by redirecting funding already available, and by finding new and innovative ways to deal with the problems.

A REHABILITATION PROGRAM FOR WATER AND SEWER SERVICES IN ONTARIO

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and
J.C. Elstad
Ministry of the Environment
Toronto, Ontario

ABSTRACT

This paper discusses the substantiation of the need for a rehabilitation program for water and sewer services through an analysis of the results of an Ontario-wide survey of the age and condition of water distribution and sewage collection systems. In addition, this paper describes some details of the rehabilitation program which the Ontario Ministry of the Environment is establishing.

RÉSUMÉ

Le ministère de l'Environnement de l'Ontario s'efforce à l'heure actuelle d'établir un programme de réaménagement des réseaux de distribution d'eau et de collecte des eaux vannes. L'exposé décrit ce programme, ainsi que les résultats de l'étude des réseaux d'aqueduc et d'égout de la province qui ont mené à son établissement.

INTRODUCTION

For some time now, the Ontario Ministry of the Environment (MOE) has been working to develop a program to encourage rehabilitation of the province's watermain and sewer infrastructure. The Ministry has made considerable progress in this regard. The central idea fueling the desire for such a program is the conviction that the combination of the extensive growth of water and sewer services in Ontario, recent government restraint, and the fact that these services are buried and therefore out of sight has lead to a deferral of necessary work on watermain and sewer infrastructure and a backlog of maintenance and replacement.

A rehabilitation program would address this backlog of necessary work with considerable savings to the Province. Rehabilitation refers to a variety of in-situ techniques for restoring the capacity or extending the useful life of watermains or sewers, but also may include, where appropriate, repair or replacement.

This report presents the findings of a study that assessed the need for a rehabilitation program in Ontario by determining the age and condition of the province's water distribution and sewage collection systems. To this end, data were gathered for water and sewer systems serving 80% of the entire serviced population in Ontario. The staff of a Canada Works Project was asked to contact every municipality in the Ontario Municipal Directory to determine whether or not there were public, communal water distribution or sewer systems in the municipalities. Questionnaires were mailed to municipalities with the aforementioned systems. A computerized database was developed with the information provided in the returned questionnaires.

EXTENT OF RESPONSE TO THE QUESTIONNAIRE

Although a serious attempt was made to encourage all municipalities with public, communal water distribution, or sewer systems to respond to the questionnaire, the rate of response fell short of 100% (as was expected). The results presented in this report are based upon questionnaires returned by municipalities for sewer systems in 286 municipalities with a total serviced population of 5,620,115 and for water systems in 344 municipalities with a total serviced population of 5,904,515.

Most of the population in Ontario that is serviced by these systems is represented in the database of returned questionnaires. Recent (1984) figures (1) indicate that 7.5 million people in Ontario are serviced by communal water systems. The returned questionnaires represent 78.73% of this serviced population. The same 1984 figures indicate that the sewer serviced population in Ontario is 7.1 million. The returned questionnaires represent 79.16% of this serviced population.

It is important to note that there are more systems than municipalities in the database of returned questionnaires. One of the objectives of this study was to determine the age and condition of individual, identifiable water and sewer piping systems. However, some municipalities contain a number of individual communities with their own individual communal water or sewer systems, making it possible to have a number of water or sewer systems in one municipality. Because of this, the results presented here represent responses for 477 water systems in 344 municipalities. In the same fashion the results presented here represent 330 sewer

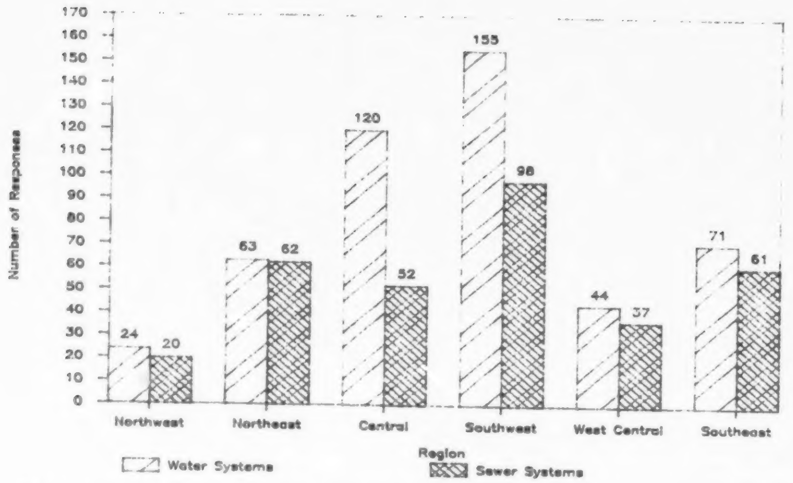

Fig. 1. Water and sewer systems in the database of returned questionnaires categorized by MOE region.

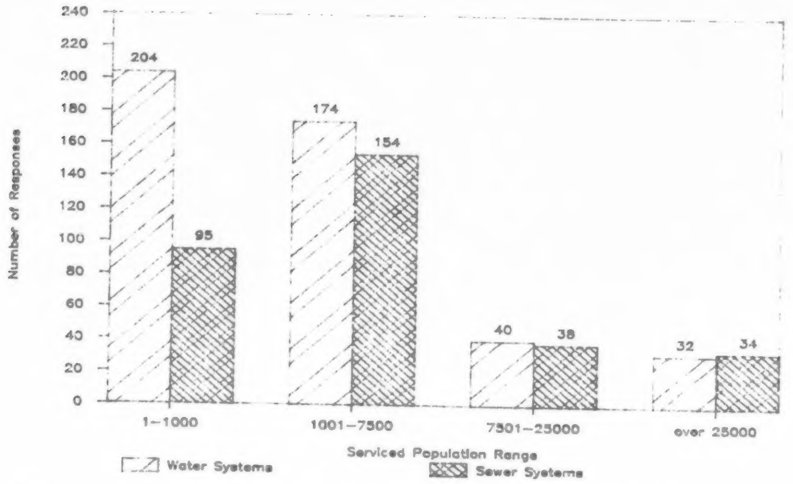

Fig. 2. Water and sewer systems in the database of returned questionnaires categorized according to serviced population.

systems in 286 municipalities. (The total number of systems represented in the various graphs in this report may vary as a result of missing data elements.)

Figure 1 is a graphic presentation of the returned questionnaires categorized according to the MOE Region in which the systems can be found. It can be seen that there is good representation from every region of the province.

Figure 2 represents a categorization of the water distribution and sewer systems in the database of returned questionnaires according to the populations which they service. It can be seen that there are a large number of small systems (204 water systems and 95 sewer systems) serving populations of less than 1,000. On the other hand there are relatively few large systems (32 water systems and 34 sewer systems) serving populations of over 25,000. This distribution of systems according to their serviced population mirrors the distribution of municipalities in Ontario according to population. Therefore, the results presented here should reflect a reliable cross-section of Ontario.

AGE OF ONTARIO WATER AND SEWER PIPING SYSTEMS

Information on the age of a water distribution or sewer system does not constitute a sufficient basis in itself on which to form an opinion of the condition of a system. It is generally known that some watermains, depending on circumstances, can have a useful life of over 100 years, while other watermains may have a useful life of less than 40 years. Nevertheless, on a broad scale (such as for all the water distribution and sewer systems in Ontario), age is still the best single indicator available of the possible need for investment in rehabilitation of these systems. The greater the age of a system, the greater the exposure of the system to such deterioration-promoting factors as frost action, erosion, ground settlement, etc.

Two methods were employed in the questionnaire to deal with the problem of gathering information on the age of water distribution and sewer systems. One section of the questionnaire requested the age of the oldest section of the water distribution and sewer systems. This is similar to setting the age of a house according to the year in which it was constructed regardless of whether or not many additions have been made to the house in subsequent years or whether or not most of the house has been renovated. Figure 3 shows the age of Ontario water distribution and sewer systems according to the age of their oldest sections. Not surprisingly, the graph shows that a large number of water systems, and particularly sewer systems, have been constructed since World War II. Nevertheless, 151 water systems and 92 sewer systems were constructed over 50 years ago. Since so many systems have very old sections, it is probable that there will be a need for a great deal of rehabilitation work in the near future.

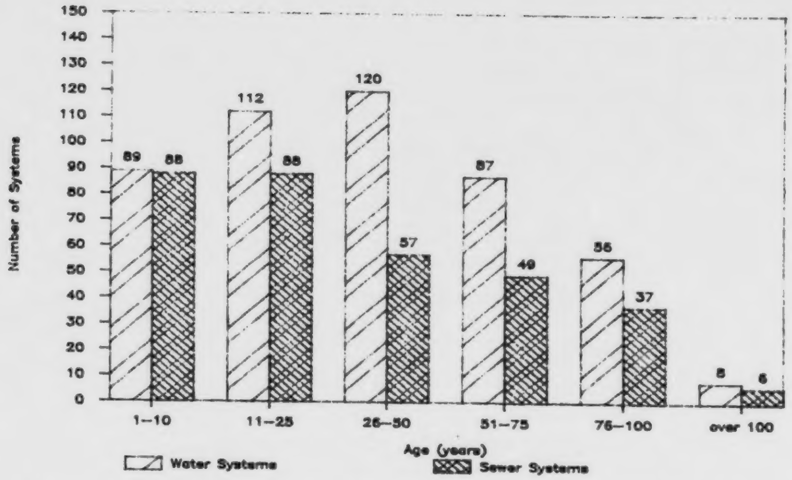

Fig. 3. Water and sewer systems categorized according to the age of the oldest section of each system.

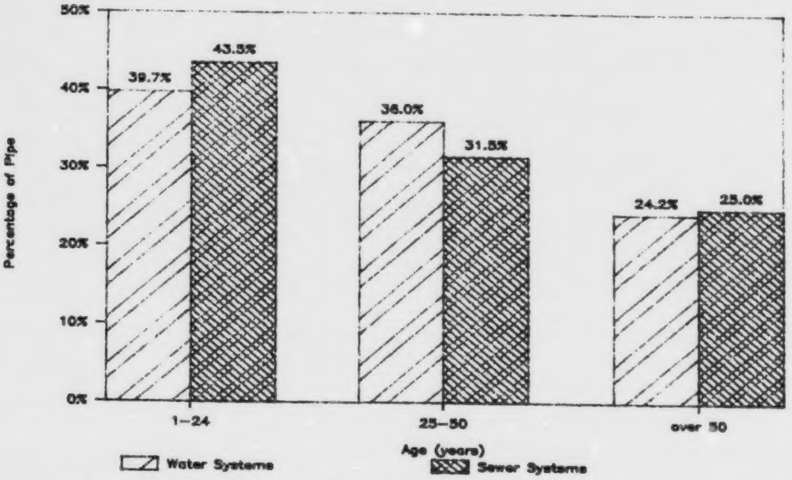

Fig. 4. The percentage of watermain and sewer pipe falling into the above age ranges.

The other approach taken to determining the age of water distribution and sewer systems in the province was to ask what percentage of each system fell into the 25- to 50-year age category and what percentage fell into the greater than 50-year age category. It was assumed that the municipalities could state the percentage of pipe in certain age ranges more easily and accurately, than they could estimate a precise average age.

Using information provided elsewhere in the questionnaire, it is possible to determine for all the watermain and sewer pipe for which information was provided, and by inference for all the pipe in Ontario, the percent of watermain and sewer that is over 50-years-old, the percent that is between 25- and 50-years-old, and the percent that is less than 25-years-old.

The results of this part of the analysis of the age of Ontario systems are shown in Figure 4. It can be seen from this graph that 24.2% of all the watermains in the database is over 50-years-old and that 25% of the sewers in the database is over 50-years-old. On the other hand, most of the pipe in the database, and by inference in the province (43.5% of the watermains and 39.7% of the sewers) is less than 25-years-old.

ESTIMATING THE COST OF A REHABILITATION PROGRAM

To arrive at an outside estimate of the cost of a rehabilitation program (to bound the problem), it is assumed that all the pipe in the province that is currently over 50-years-old will need to be replaced within the next 50 years. Of course, it is hoped that, through a rehabilitation program that includes some replacement, considerable savings may be achieved over replacement alone.

Some of the pipe that is currently over 50-years-old is, in fact, as old as 100-years. So, under this assumption, pipe can be between 50- and 150-years-old at its time of replacement. It may be that all of this pipe will not need replacement over this period of time, but then a certain amount of pipe currently less than 50-years-old will need replacement instead. It is assumed that the amount of pipe having a longer-than-expected lifespan will equal the amount of pipe having a shorter-than-expected lifespan.

With these assumptions, the total annual cost for the rehabilitation of watermain and sewer in the province over the next 50 years should be at most $150 million. (This figure assumes equal annual replacement over 50 years of the estimated 8,087 km of watermain, and 8,046 km of sewer currently over 50-years-old. The estimates of the cost of replacing watermain and sewer are $475,000 per km and $454,00 per km, respectively) (2).

For the sake of simplicity, this estimate of the cost of a rehabilitation program has not taken into account the effect of government borrowing or the effect of inflation. These factors would have increased the estimated annual cost. Also, due to the non-uniform distribution of watermains and sewers according to their age in Ontario (and Figure 4 shows that there are more new facilities than old facilities), the required spending level may need to increase some time from now as the newer facilities age.

CONDITION OF ONTARIO'S WATER DISTRIBUTION SYSTEMS

Rate of Watermain Breakage

For the water distribution systems represented in the database of returned questionnaires, a total of 6,497 watermain breaks per year were reported. This represents an average of 24.7 breaks per 100 km per year. If an average rate of watermain breakage of 10 breaks per 100 km per year across the province could be achieved through a rehabilitation program, then the savings in expenditures on the repair of watermain breaks in Ontario would be $14,728,000 per year. (This figure assumes a repair cost of $3,000 per break.)

With reference to Figure 5, it can be seen that 325 of the water distribution systems in the database reporting on the length of their systems were experiencing breaks, 111 water distribution systems reported no breaks at all. Of the systems reporting breaks, more systems fell into an interval of break rates between 11 and 25 breaks per 100 km per year than into any other interval. Of particular concern, however, is the large number of systems with very high rates of watermain breaks; 78 systems had break rates over 50 breaks per 100 km per year. In Figure 6 the percentage of these systems in the different break rate categories is depicted. Of the water distribution systems in the database which are experiencing breaks, 24% have break rates greater than 50 breaks per 100 km per year.

The severity of this problem of high rates of watermain breakage in Ontario communities is mitigated by the fact that many of the water distribution systems with high break rates are very small. Figure 7 demonstrates the number of water distribution systems serving at most 7,500 people and the number of systems serving more than 7,500 people for each break rate interval. For example, for the 61 water distribution systems experiencing breaks at rates no greater than 10 breaks per 100 km per year, 41 have serviced populations no greater than 7,500; 20 have serviced populations greater than 7,500. For the 35 water distribution systems with break rates greater than 100 breaks per 100 km per year, 34 of the systems serve populations no greater than 7,500. (In fact, 27 of these water distribution systems serve populations no greater than 1,000.)

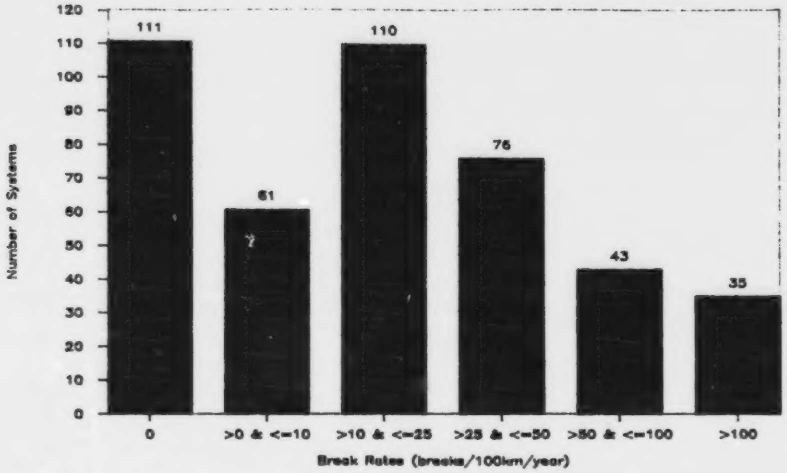

Fig. 5. The distribution of break rates for water distribution systems.

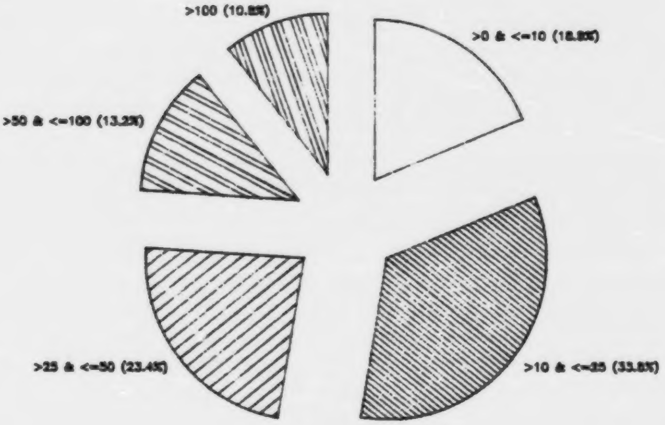

Fig. 6. The percentage of water distribution systems falling into the above break rate categories for those systems reporting breaks.

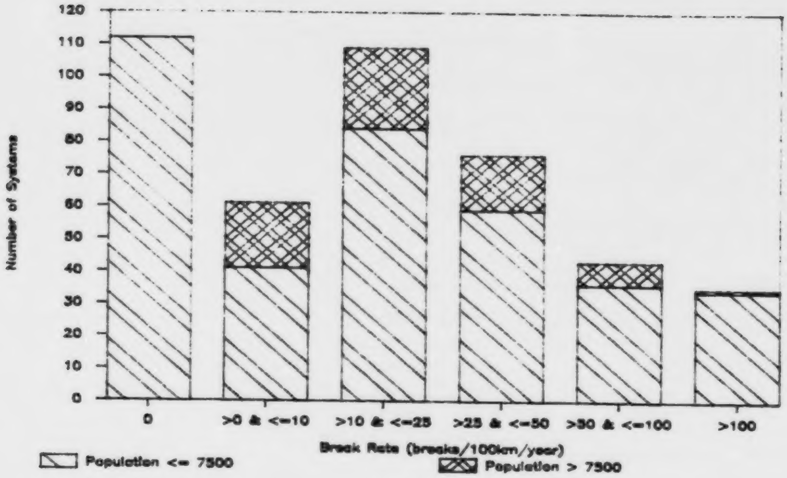

Fig. 7. The distribution of watermain break rates further categorized according to system size (serviced population).

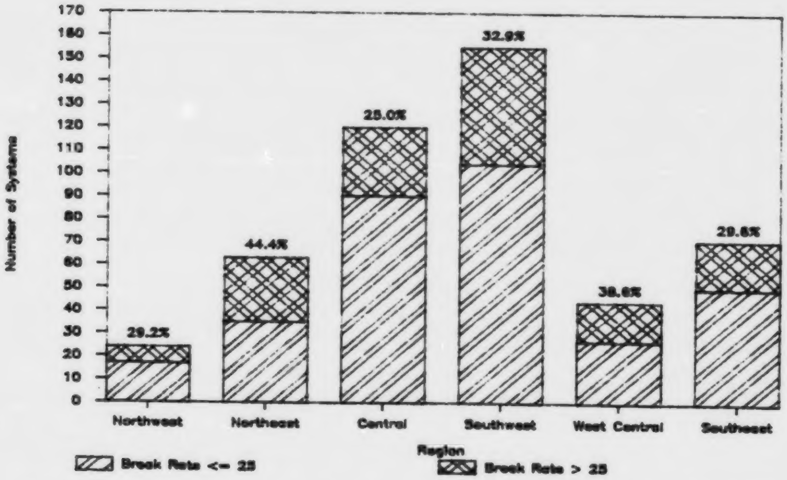

Fig. 8. The number of water distribution systems with high or low break rates for each MOE region.

A high rate of watermain breakage in a very small community may not be as severe a problem as it may seem. For a hypothetical small community with a water distribution system 2 km in total length and serving approximately 400 people, a watermain break history of 2 breaks/year would be equivalent to a break rate of 100 breaks per 100 km per year. Although this is a very high rate of breakage, the yearly cost of repairing these breaks would not be too burdensome ($6,000 per year at $3,000 per break). Moreover, the watermain breaks in this hypothetical community could be due to isolated, temporary phenomena occurring in one bad stretch of pipe. The replacement of this stretch of pipe could result in a period of many years without breaks throughout the small system.

Notwithstanding the foregoing discussion, it would seem from the high numbers of small communities with high rates of watermain breakage that there is a problem in Ontario due to the location of small water distribution systems in conditions that are probably adverse. This leads to a disproportionate share of local resources being spent on the more or less constant repair of the water distribution system, and suggests a worsening and potentially serious problem in the future.

In Figure 8, the number of systems in each region reporting high rates of watermain breakage (greater than 25 breaks per 100 km per year) and low rates of watermain breakage (at most 25 breaks per 100 km per year) are shown. At the top of each bar the percentage ratio is shown that the number of systems with high rates of breakage represents to the total number of systems reporting breaks in a region. From these percentages it would appear that the most severe problems occur in the Southwest, West Central and Northeast regions (32.9%, 38.6% and 34.4% respectively of the systems reporting breaks in these regions, report high rates).

Overall, the watermain breakage problem is worse in the north than in the south. The average rate of watermain breakage for the two northern regions is 28.7 breaks per 100 km per year while the average rate in the four southern regions is 24.2 breaks per 100 km per year.

Reasons for Breaks

Watermain failures can occur in a number of ways. There are beam failures which appear as circumferential breaks that can be caused by a loss of pipe bedding support and occur primarily in small diameter watermains. There can be longitudinal breaks along the pipe length due to crushing loads from above which occur more often in large diameter watermains. There also can be pin hole or blow out breaks due primarily to corrosion or material failure (3). (This discussion is not meant to be exhaustive -- there are other types of watermain breaks such as separation at bends and tees.)

These types of watermain failures have various causes and as a result the range of responses concerning the major reasons for watermain failure in the returned questionnaires was very broad. For ease of analysis, the responses have been grouped into several categories which are shown in Figure 9.

The most common reason given for watermain breaks is frost (28.9% of responses). This category includes all temperature effects, but the most common responses by far in this category were frost, frost heave, or frost jacking. The prevalence of frost as a reason for watermain breaks should not be surprising given the large number of systems in Ontario constructed in rocky terrain and/or subjected to severe winter temperatures.

Watermain failures associated with construction methods were the second most common category of responses (19.3% of responses). This category includes rocks in the backfill, tamping of bedding either poor or absent, etc. It also includes a few responses which imply that failures were due to adjacent construction (these problems may have been unavoidable). Interestingly, corrosion was only the third most common reason given for watermain failures (11.7% of responses). This does not imply that corrosion is not an important problem, especially for some large systems, e.g. Scarborough (4).

The distinction between some of the other categories of reasons for watermain failures may not be as clear as might be desired. For example, ground movement (the fourth most common reason given at 11%) includes various types of loss of bedding support (e.g. erosion, differential settlement, etc.) some of which may be associated with construction methods such as poor bed preparation. Age (8.2% of responses) is not a very clear statement of a reason for watermain failures (it could overlap with corrosion), but this response was so common that it was included as a category. The "other" category of responses (11.9% of responses) included a broad range of responses (some of them not reasons for breaks at all) that could not be accommodated in any of the categories.

By way of summary, there are four main causes of watermain failures across the province -- frost (at about 30% of responses), construction methods (at about 20% of responses), corrosion and age (material failure -- at about 20% of responses), and ground movement (loss of bedding support -- at about 10% of responses).

Water Losses

Water lost through leakage from municipal water distribution systems due to the condition of the pipes is of primary concern in assessing the condition of these systems in Ontario. However, the rate of leakage is not easily determined. Also, many systems in Ontario have very little metering. Therefore, the questionnaire requested, instead, the percentage of total flow for a system that is unaccounted for.

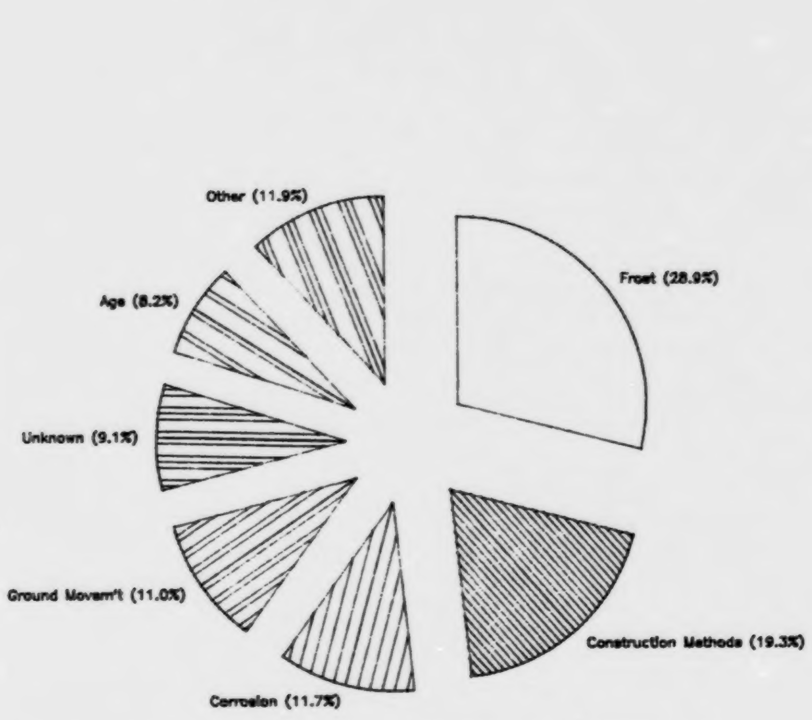

Fig. 9. A percentage breakdown of reported reasons for watermain failures.

The number of systems reporting percentages of unaccounted for water in various ranges is shown in Figure 10. The degree of response to this question was not as great as for other questions. Data were provided for 268 water distribution systems or 56% of the systems in the database. This seems to indicate that this question was often difficult to answer. However, these 268 systems represent a serviced population of 4,924,609; 83% of the total serviced population listed in the database. (66% of the total population serviced by communal water systems in Ontario.)

Figure 11 demonstrates the percentage of the 268 systems in each category of unaccounted for water. It is pleasing to observe that 37 systems, or 13.8% of the 268 reporting systems, indicated that wastage of water was next to nothing. A further 92 systems, or 34.3% of the total systems, reported water losses at 1% to 5% of total flow. However, 86 systems, or 32% of the total, reported water losses above 10%, indicating a considerable waste of resources through lost water.

The average water loss for the 268 (weighted by the serviced population) is 12.5%. If a rehabilitation program across the Province were able to reduce the unaccounted for water losses by one quarter, then the savings would be $4.8 million per year. (This figure assumes a 12.5% rate of water loss for communal water systems serving 7.5 million people and a per capita demand of 100 Imp. gal./day. The annual water loss for these systems is, then, estimated to be 34.2 billion Imp. gal. The operating cost for supplying potable water is estimated to be $0.56/1,000 Imp. gal. based on expenditures at MOE operated facilities.)

CONDITION OF ONTARIO SEWER SYSTEMS

Combined Sewer

Eighty-one of the 330 sewage collection systems represented in the returned questionnaires have some combined sewer in their systems. Based on the percent of each system that was reported to be combined and the serviced population, it is estimated that there are 4,712 km of combined sewers in these 81 systems.

A minimum estimate of the cost to separate all the combined sewer remaining in the province would be the cost to provide storm sewers to relieve all the remaining combined sewers in these 81 sewage collection systems. This cost would be:

4,712 km x $605,000.00/km* = $2.85 billion.

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* This unit cost estimate [5] is based on a detailed estimate of the cost of local storm sewer construction in the City of York. Sewers ranged from 300 mm to 600 mm in

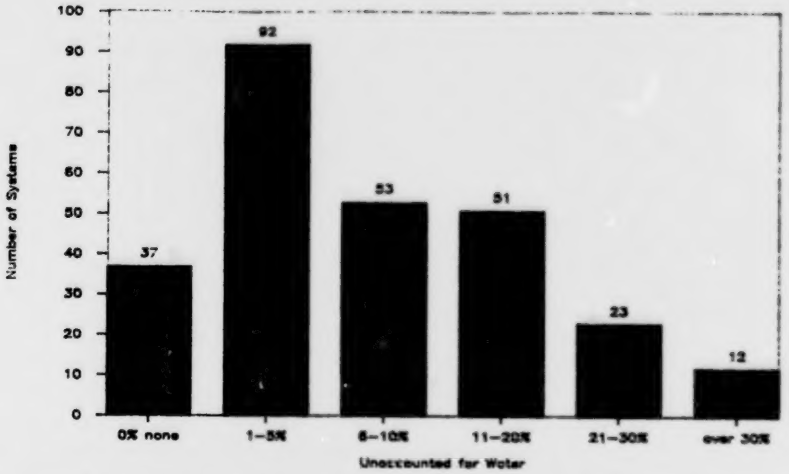

Fig. 10. Water distribution systems categorized according to unaccounted for water as a percentage of total flow.

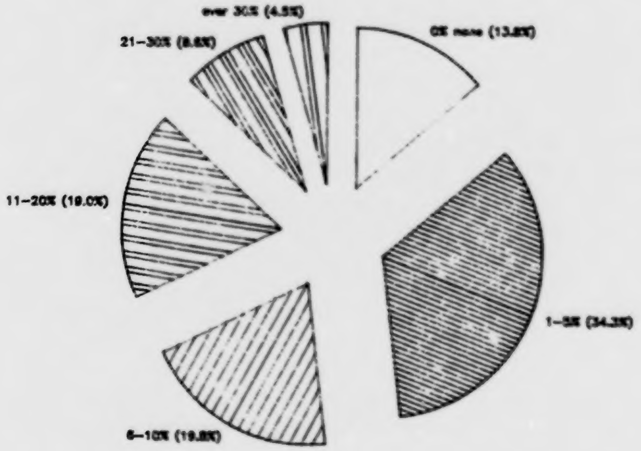

Fig. 11. The percentage of water distribution systems with the above rates of unaccounted for water.

diameter, and construction at various depths was called for. This unit cost estimator does not include the cost of house service connections.

This is a conservative estimate because the database of returned questionnaires does not include all the sewer systems in the province which have combined elements.

Infiltration

Of the 330 sewage collection systems represented in the database of returned questionnaires, 170 have infiltration problems. Municipalities were asked to report the most important reasons for infiltration for sewage systems with infiltration problems. In Figure 12, the frequency of certain responses concerning causes of infiltration is shown for the 170 sewer systems with infiltration problems. It is interesting that 42% of the responses concerning causes of infiltration involve problems with pipe joints, because the leakage at these pipe joints often can be reduced significantly with current rehabilitation techniques. Of the 42% with pipe joint problems, 20% involve deteriorated joints, meaning that the seal at the pipe joint has failed; 11% involve leaking, off-set joints, meaning that the pipe ends have separated at the joint, and another 10% of the joint problems involve open joints, referring to the practice, mostly in older types of pipe installations, of not providing a seal at the pipe joint at all.

In addition, 23% of infiltration problems are caused by the structural failure of the sewer pipe. Cracked pipe represents 17% of the responses given concerning causes of infiltration, while broken or collapsed pipe represents another 6% of the causes of infiltration. Although the leakage caused by these problems can be reduced significantly with current rehabilitation techniques, pipe replacement may be a more feasible alternative solution in some cases.

Another 8% of infiltration problems are caused by leaking house service connections. This is a very important aspect of the infiltration problem, since the total length of service connections often equals the length of the sewage collection system. (Leaking house service connections are probably a more important problem than the 8% rate of response above would indicate.) Finally, 6% of infiltration problems are caused by deteriorated manhole walls, bases and troughs.

Inflow

Of the 330 sewage collection systems for which information was provided, 207 have inflow problems. Figure 13 graphically demonstrates the frequency of the major causes of inflow for the 207 systems with inflow problems.

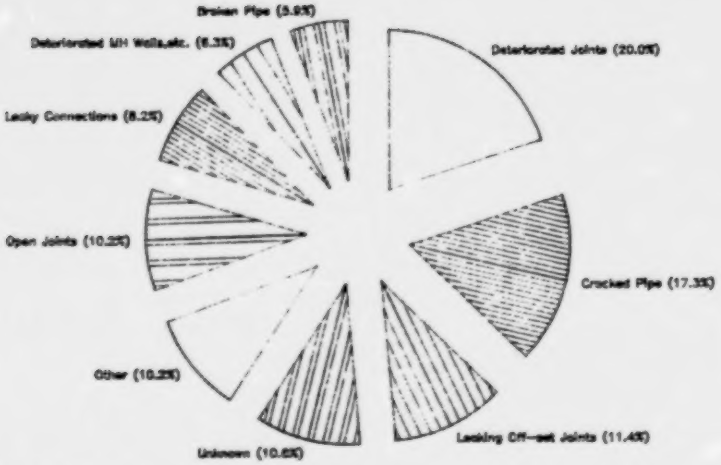

Fig. 12. A percentage breakdown of reported causes of infiltration into sewer systems.

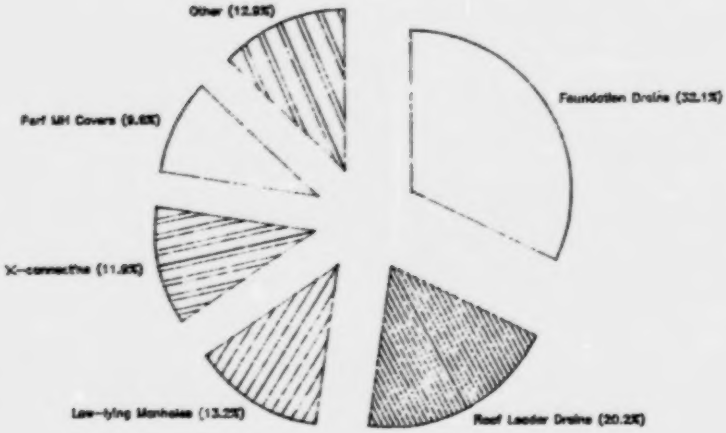

Fig.13. A percentage breakdown of reported causes of inflow into sewer systems.

Of the major causes of inflow reported for these 207 systems, 32% are reported to be foundation drains connected to the sewer system. This is generally a very expensive problem to remedy because disconnection of these foundation drains requires extensive excavations, mostly on private property.

The other major causes of inflow are less difficult to remedy. Roof drains (20.2% of the reported causes of inflow) are relatively inexpensive to disconnect, although disconnection of roof drains can aggravate flooding problems if they exist. Problems at the top of manholes are also relatively inexpensive to solve. Manholes are involved in 23% of reported causes of inflow -- either perforated manhole covers (9.6% of reported causes) or low lying manholes (13.2% of reported causes). Finally, 12% of the major causes of inflow involve cross connections from storm sewers. Disconnection of these inputs would involve excavations. However, these excavations would be fewer in number than those required to disconnect foundation drains, and they would be mostly on public property.

Compounded Problems

The problems of infiltration, inflow and combined sewers tend to overlap. For instance, of the 170 sewage collection systems that have infiltration problems, 147 have inflow problems as well. Furthermore, of the 170 sewage collection systems with infiltration problems, 54 systems have combined sewer elements in the systems and inflow problems as well.

This compounding of problems poses a special question with regard to a rehabilitation program for aging and deteriorating sewers in Ontario. The rehabilitation of these sewers, through reducing infiltration, would achieve the goal of extending the useful life of these facilities, but might achieve the goal of reducing extraneous flow only partly. It may be that, in many cases, the goal of reducing extraneous flows would be served better by reducing inflow or eliminating remaining combined sewers. This, however, does not involve rehabilitation of existing facilities but rather policy decisions regarding the strict enforcement of sewer use by-laws or the construction of storm sewers to relieve remaining combined sewers.

Cost of Treating Extra Flows

The 147 systems which have both inflow and infiltration problems have a total sewer serviced population of 3,160,327. The total annual sewage treated for these systems is estimated to be 146 billion imperial gallons, of which 30.7 billion imperial gallons is estimated to be extraneous flow (inflow and infiltration). (Extraneous flow is estimated to be 21% of total flow) [6]. If half of this extraneous flow could be eliminated through a province-wide rehabilitation program (that includes efforts to eliminate inflow), $5 million per year in operating costs for sewage treatment could be saved. (The operating cost of treating sewage is estimated to be $0.33/1,000 imp. gal based on operating costs at MOE-operated facilities.) If the sewage systems not included in this database are considered as well, the savings could be as high $6.4 million per year.

CONCERNS OF ONTARIO'S MUNICIPALITIES

The municipalities completing the questionnaire were asked for their water distribution system(s) to rank in order of importance such concerns as low pressure, poor water quality related to the condition of system pipes, leakage, watermain break frequency or any other concern. Figure 14 graphically demonstrates the frequency with which these concerns were given first priority for the 300 systems for which information was provided. Not surprisingly, concerns over poor water quality were considered most important most often (29.5% of responses). However, it may be that for some of these responses, the cause of the poor water quality is at the water source and not in the distribution system.

Watermain break frequency (ranked first in 21.9% of the responses) and low pressure problems (ranked first in 19.7% of the responses) are of about equal concern. Low pressure problems in the water distribution systems in small Ontario communities are often due to the presence of old, small diameter, cast iron watermains.

Leakage was considered most important for just 14.5% of the systems. Also, for 14.5% of the systems, some other problem was of greatest importance. This (other) category covers a broad range of responses.

The opinions of municipal officials with regard to the present condition of their water distribution and sewage collection systems are categorized and presented in Figure 15 and it can be seen that 299 water systems and 195 sewer systems are considered to be in good or acceptable condition; 87 water and 62 sewer systems are considered to need some repairs; and, finally, 64 water systems and 47 sewer systems either need extensive repairs or are in unacceptable condition.

It can be expected that a majority of the systems would be in either good or acceptable condition, especially considering how many systems have been constructed relatively recently. In these results, 66% of water systems and 64% of sewer systems are considered to be in either good or acceptable conditions. However, the fact that over 30% of water and sewer systems in the returned questionnaires (and by inference in the entire povince) need some repair, need extensive repair, or are in unacceptable condition seems to warrant attention on the part of senior governments to the matter of encouraging the rehabilitation of these systems.

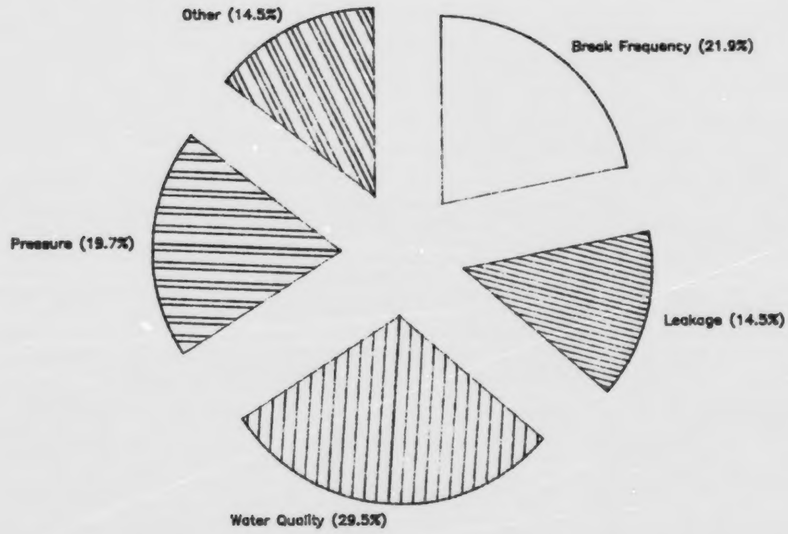

Fig. 14. Areas of primary concern for water distribution systems.

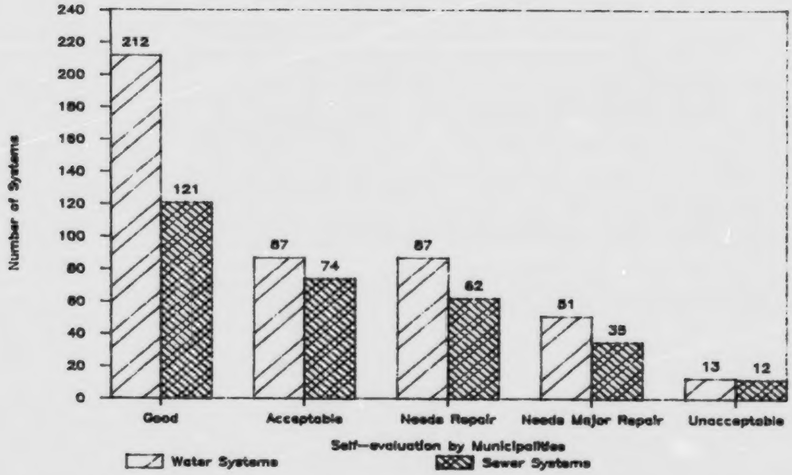

Fig. 15. The present condition of water and sewer systems.

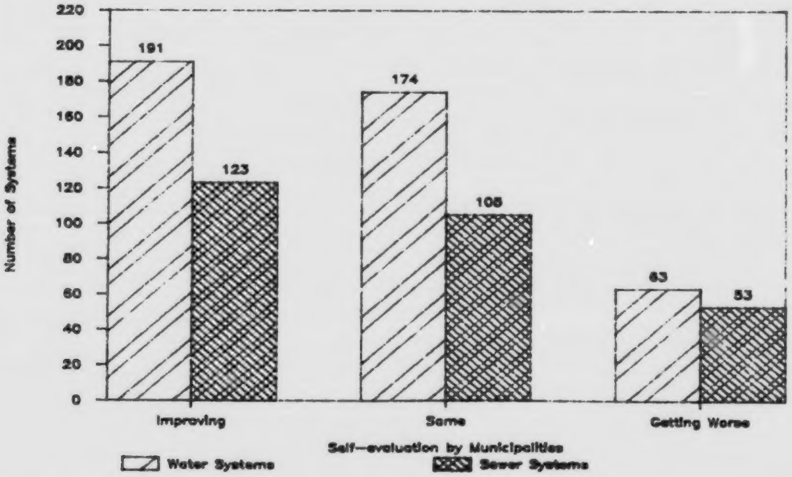

Fig. 16. For water and sewer systems, the change in condition over the last 15 years.

In Figure 16, the opinion of municipal officials with regard to the change in condition of their systems over the past 15 years is depicted by category. The condition of 191 water and 123 sewer systems is reported to be improving. For 174 water and 105 sewer systems, the condition is reported to have stayed the same. However, for 63 water and 53 sewer systems, the condition has been getting worse.

It seems that there might be considerable reluctance on the part of municipal officials to admit that the condition of their water or sewer systems has been getting worse in recent history. It is relatively surprising, therefore, that the condition of as many as 63 water and 53 sewer systems is seen to have been worsening. This is probably indicative either of severe problems with these systems or of substantial financial obstacles to the solution of these problems.

NEW DIRECTIONS

The Government of Ontario has approved an allocation of $1.5 million in the MOE's 1986/87 fiscal budget to provide financial assistance for the preparation of "needs studies" for water distribution and sewage collection systems in Ontario municipalities. The government is prepared to allocate as much as $4 million in the 1987/88 budget for this purpose. Depending on a municipality's population, the MOE will contribute not less than 50% of the cost of the study, net of contributions from other agencies.

These needs studies are considered to be the cornerstone of the Infrastructure Rehabilitation Program for water and sewer services. The purpose of these needs studies is to develop a multi-year, cost-effective rehabilitation program, as required, for Ontario municipalities based upon a complete inventory of the water distribution and/or sewage collection system.

The funding of actual rehabilitation construction is pending consideration by the cabinet of Ontario.

Terms of Reference

The terms of reference for these needs studies will be prepared on a case-by-case basis, but, in general, will cover the following points (by way of example, for sewer systems):

- development of a complete inventory of the sanitary sewer system including the location, construction material, size, length and age of pipes, as well as soil type, repair and maintenance records and other relevant data;
- entry of this inventory data onto micro-computers using a designated software program;

- analysis of repair records in order to determine the most deficient elements;
- determination of the physical condition and structural integrity of the sewers, appurtenances and service connections;
- undertaking, as necessary, of an inflow/infiltration survey for the sewer system;
- undertaking, as necessary, of a TV camera inspection of the sewer system;
- review of the existing sewer maintenance program to determine improvements to the program;
- review of the existing sewer use by-laws and their enforcement to determine the need for improvements;
- formulation of alternatives for a rehabilitation program and the evaluation of these alternatives according to cost-effectiveness; and
- setting of priorities and the formulation of a multi-year rehabilitation program.

A typical terms of reference document for a water distribution system Needs Study would include all the above points (except those that apply exclusively to sewer systems), as well as such activities as investigations of internal/external corrosion, flow and pressure testing and leak detection surveys.

Procedures

Interested Ontario municipalities may contact MOE Regional or District Offices to obtain more information or to apply for financial assistance for water distribution and/or sewage collection system needs studies.

Acknowledgements

The salaries of the exceptionally bright group of people that formed the staff for this project were provided by the Federal Department of Manpower and Immigration as part of what was called, at that time, a "Canada Works Project". The members of this staff were (in no particular order): Rudy D'Agostino, Cropthorne Lee, Will Heywood, Elio Covello, Richard Bennett, Richard Chiu, and Dominic Nigro.

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Finally, and most importantly, the municipalities and municipal officials that took the time and trouble to provide the information that is the substance of this report are gratefully acknowledged.

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RENEWING URBAN TRANSPORTATION INFRASTRUCTURE

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ABSTRACT

In many Canadian municipalities, deferred maintenance has resulted in a significant deterioration of existing roads and public transit facilities with correspondingly high user costs. Moreover, because of inadequate attention to periodic maintenance at appropriate times in the life-cycle of these facilities, in many cases, premature rehabilitation and reconstruction will be required, leading to excessive and unnecessary expenditures for both municipal and provincial governments.

Many of these expenditures could have been avoided through better planning and management of all the funds available for urban transportation within a comprehensive framework that examines needs for maintenance and new construction.

This paper discusses some of the reasons why elected officials and senior administrators have neglected maintenance needs in the past, and suggests means of obtaining a better balance in the future in overall expenditure patterns for urban transportation facilities.

RÉSUMÉ

Dans un grand nombre de municipalités canadiennes, le report des travaux d'entretien a entraîné une détérioration notable des routes et installations de transport en commun existants et fait s'accroître proportionnellement les coûts imputés aux usagers de ces services. De plus, le manque d'attention accordée à l'entretien périodique des installations au cours de leur durée utile a, dans bien des cas, obligé à réaménager ou à reconstruire ces installations plus tôt que de n'aurait été nécessaire autrement et a occassionné ainsi des dépenses inutiles excessives pour l'administration municipale et le gouvernement provincial.

Bon nombre de ces dépenses auraient pu être évitées, si on avait mieux plainfié et géré les crédits affectés au transport urbain en les considérant dans un tout intégré tenant compte des besoins d'entretien et de construction nouvelle.

L'exposé aborde certaines des raisons pour lesquelles les représentants élus et les hauts dirigeants ont négligé l'aspect entretien des installations par le passé et suggère des moyens de parvenir à un meilleur équilibre de l'ensemble des dépenses relatives aux installations de transport urbain.

INTRODUCTION

In many municipalities, senior administrators responsible for roads and traffic are concerned about available budgets for maintenance, rehabilitation and reconstruction. The cumulative effect of shortfalls between needed expenditures and available resources in recent years results in a backlog of deferred maintenance. Eventually, much larger expenditures will be incurred than otherwise would be required, had periodic maintenance been undertaken at appropriate points in the life cycle of existing infrastructure.

Clearly, one solution to the problem of deferred maintenance is simply to apply more pressure for greater funding. In times of financial austerity, however, such pressures must compete with similar demands for additional spending in transportation system expansion, as well as other public sector activities (e.g.,health and education).

Another obvious approach for deaing with the problem is to slow down the construction of new facilities and divert existing funds to accelerated maintenance and rehabilitation. This is not an easy task, however, given the rapid population growth in areas that are underserviced in terms of existing transportation facilities, the political nature of spending in the public sector, the desire for "visibility", and the expansionist goals often exhibited by large transportation organizations.

Moreover, in most Canadian municipalities, cost-sharing arrangements between municipal and provincial governments often mean that a municipal government, which is prepared to put greater emphasis on maintenance and rehabilitation, cannot really proceed with those priorities if the provincial government does not share the same enthusiasm about the application of its transfer payments.

Under these circumstances, it would be more appropriate if municipal governments extracted the funds needed for maintenance and rehabilitation from savings that can be obtained through more efficient utilization of all the financial resources available for transportation.

LIFE CYCLE CONCEPTS

In the provision of any urban transportation service, three fundamental components of cost should be considered in determining the scheduling and magnitude of investment in maintenance and rehabilitation. These components include:

- the capital costs associated with land aquisition, design, and initial construction;
- the costs of maintaining facilities and equipment; and
- those costs incurred by operating the system.

In most public sector accounting, it is usually only the first two cost components that show up in public accounts.

Replacement or Continued Maintenance?

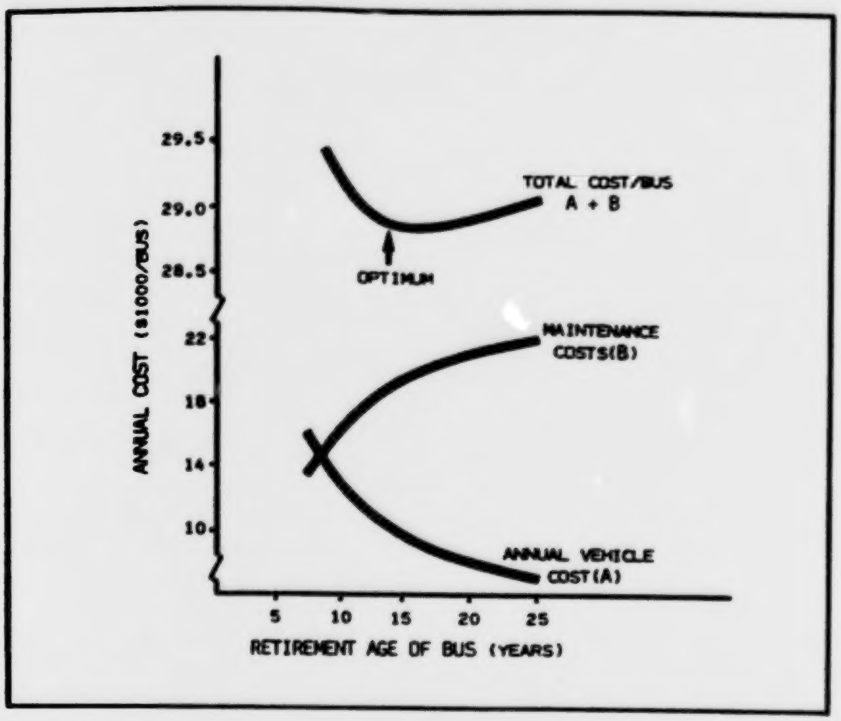
Public Transit Equipment. Consider, for example, the case of public transit equipment such as buses or rail transit rolling stock. As with private automobiles or any piece of machinery, these vehicles have an initial cost, as well as continuing and periodic maintenance costs that depend upon vehicle utilization and the age of the equipment. These distinctions between capital and current costs are not always entirely clear, because replacement of a major vehicle sub-system, such as the power plant, generally treated as maintenance, cannot always be distinguished from capital investment in vehicle replacement.

For this simple example, however, the concept of life cycle costing has been illustrated in Figure 1. In this diagram, the annual costs of vehicle "ownership" are shown as a function of service life (or retirement age). Obviously, from a straightforward application of an amortization factor (capital recovery factor), the longer the vehicle is maintained in service, the lower the annual costs of depreciation and interest on the investment. In general, however, the longer a vehicle is used, in terms of years of service, the higher the annual maintenance costs, some of which are fixed (for example, cleaning), but most of which can be related to hours of operation or annual mileage. Combining the maintenance and capital costs of a bus, the optimum service life can be determined by the point at which it would be more economical for the operating authority to replace the vehicle than to continue to maintain it in service. If adequate funds are not available to replace vehicles at the optimum age, then additional funds will be needed to compensate for maintenance costs that generally increase more rapidly beyond this point in time.

This optimum point in the life cycle of capital and maintenance costs obviously is influenced by the borrowing rate included in the amortization factor, and by any distortions introduced into the analysis as a result of differential subsidy policies

Figure 1

ECONOMIC ANALYSIS OF BUS RETIREMENT AGE



Source: E. Beauchamp, "Retirement and Repair Policy at MUCTC," presented to the fall committee meeting of the Canadian Urban Transit Association, Toronto, 1971.

between capital expenditures, such as the purchase of a bus, and current expenditures, such as bus maintenance costs.

Roads and Fixed Plant Components. Similar relationships apply in the case of roads and the fixed plant components of rapid transit, light-rail transit, and commuter railways (i.e., track, signals, yards, and electrification). The problems of deferred maintenance are greater for rail transit systems, however, than for roads, because the impacts of inadequate maintenance (e.g., derailments due to improperly maintained track structure or collisions resulting from a signal system malfunction) are much more disastrous from the standpoint of safety. Transit authorities therefore, at least in Canada, already place maintenance of fixed plant ahead of system expansion in their financial priorities.

In the case of roads, the life cycle approach used by the Roads and Traffic Department of Metropolitan Toronto provides a useful example. The Metro roads department divides maintenance and rehabilitation into two basic activities:

- resurfacing, which involves the replacement of asphalt wearing surfaces, and
- reconstruction, which involves the replacement of both the concrete base and the asphalt pavement.

Setting aside the costs of land acquisition and engineering design, Metropolitan Toronto has established 45 years as the optimum life cycle for pavement management of arterial roads on the basis of the following schedule:

Year	Activity
0	new construction or reconstruction
20	resurfacing
31	resurfacing
45	reconstruction

This schedule, which is based on many years of experience, suggests that road deterioration accelerates with age and that deferral of resurfacing due to insufficient funds shortens the life cycle of the road, requiring major reconstruction at an earlier point. Since the costs of reconstruction differ by an order of magnitude from the costs of resurfacing, deferring needed maintenance simply means that future costs will be much higher. In other words, "a stitch-in-time saves nine".

The Difference is User Costs. In considering the life cycle costs of roads in comparison with transit vehicles, however, there is an important difference which relates to user costs. When road surfaces deteriorate, aside from any consideration of additional travel time or discomfort, higher costs are experienced by owners of autonobiles and trucks due to increased vehicle maintenance and energy consumption. To place these costs in perspective, consider that in the greater Toronto area, provincial and municipal government agencies together spend approximately $1 billion annually for the construction, maintenance and operation of road and transit systems. Users of these systems, by contrast, are estimated to spend about $8 billion annually in the costs of vehicle maintenance and operation. Obviously, transportation agencies and authorities maintain existing systems in order to reduce user costs, but there are some important accounting difficulties.

During times when road improvements are made (e.g., repaving and reconstruction), for example, there is almost always serious traffic congestion and correspondingly higher user costs. The time period of these activities could be shortened, thereby reducing total user costs, by having the relevant government agencies pay higher costs for overtime and weekend work. From the standpoint of the responsible road agency, however, incurring higher costs to accelerate a maintenance project would make it appear as though productivity had been reduced, unless the agency could quantify and take credit for the additional user benefits.

BASIC ISSUES

For whatever reasons, many of our municipal road networks have deteriorated beyond the point where normal maintenance programs can be effective. Additional funding is required now if the costs of rehabilitation and reconstruction are not to be increased by an order of magnitude in the future.

Obviously, today's problems of adquately maintaining the urban transportation infrastructure are a reflection of the general state of the economy, the objectives of government to control spending and limit increases in taxation, and policies with respect to the treatment of road user charges. Even within the constraints of existing funding levels, however, there are a number of basic impediments to accelerating the emphasis on maintenance and rehabilitation.

Needed: A Rationale for Comparing Requirements. First, in most cases, responsible agencies have not been particularly forthcoming in developing a rationale for comparing requirements for rehabilitation with needs for system expansion within the limits of available funding. Such agencies tend to focus on the capacity deficiencies of existing systems to handle traffic growth as a means of justifying proposals for major new road facilities. Similar exposure has not been given to the problems of maintenance and rehabilitation even though, in many American and certain Canadan cities (which will remain nameless in interests of diplomacy) the quality of road infrastructure borders on a deplorable state.

Deemphasis on Politically Glamourous Activities. Second, it must be recognized that ribbon cutting is almost always a preferable political activity to filling potholes or resurfacing existing facilities, at least in terms of media exposure. As a result, elected officials have a preoccupation with engaging in new projects which have a clearly identifiable constituency, such as motor leagues, trucking associations, and land developers, at least in relation to the silent majority of those who now use existing systems.

Managing According to Necessity. Third, at the risk of offending responsible authorities, established organizations may be overly influenced by organizational structures that place higher visibility and emphasis on planning, design, and construction than on the day-to-day activities associated with maintenance and rehabilitation. Both career-wise and profile-wise, managerial positions related to planning or construction are more prestigious than those related to maintenance.

Apportioning Funds According to Necessity. Fourth, there are certain historical precedents with respect to the allocation of funds which are difficult to break. Thus, municipal governments have become accustomed to spending a certain proportion of their budgets on maintenance and a certain proportion on system expansion, even when, at least in already established areas, system expansion may no longer be as important. In other words, in some cases, needed maintenance programs may be starved because of unjustified expenditures in system expansion based on historical expenditure patterns.

Upgrading Spending Priorities. Fifth, because of the political controversy surrounding road expansion characteristic of the 1960s and 1970s, many governments (both municipal and provincial) transferred more emphasis to public transit. Those policies, which may no longer be as relevant today, have introduced long-term biases in spending priorities to the exclusion of adequate funding for road improvements, including maintenance.

Equitable Subsidy Policies Needed. Sixth, funding programs and subsidy policies often introduce distortions in the decision-making process which militate against greater attention to maintenance and rehabilitation. In Ontario, for example, selecting the optimum time for transit vehicle replacement is influenced by the fact that maintenance costs are subsidized at a different rate by the provincial government than the capital costs of new vehicle acquisitions. Thus, while it may be more economical from the standpoint of a particular transit agency to replace vehicles at an earlier time, provincial expenditures actually increase, leaving fewer net funds available for other transportation programs such as maintenance. Moreover, differential subsidy policies between modes, as between roads and transit, can encourage a municipal government to give higher priority to projects that cost the municipality less (e.g., 25 cent dollars for transit capital improvements) than other more worthwhile projects such as road maintenance, that must be paid for with 50 cent dollars.

Establishing Need-Related Source of Revenue. Finally, probably the major problem with funding all road improvements, including maintenance and rehabilitation, is the lack of any clearly identifiable source of revenue that can be related to need. In contrast to public transit where both revenues and subsidies, which can be used for infrastructure maintenance, are directly related to ridership, increased traffic on roads which accelerates maintenance needs produces no additional sources of revenue. This occurs because no portion of road user charges generated in urban areas, such as fuel taxes, is earmarked for road improvements. All such revenues are allocated to the provincial consolidated revenue fund.

FUTURE DIRECTIONS

The increasingly important problem of infrastructure deterioration obviously can be treated by one or a combination of two basic approaches. The first simply involves obtaining more funds for maintenance and rehabilitation, the second, diverting some of the existing funds earmarked for system expansion to maintenance priorities.

Obtaining More Funds

Obtaining more funding involves a struggle with the general pressure on governments to reduce spending, or at least "flatline" existing allocations, as well as competition from other sectors where demands for government finance also are growing, particularly for heath, education, and employment creation programs. Moreover, even though road users generate significant funds, there is an obvious reluctance to earmark these funds for road maintenance. The second course of action is also difficult, partly for some of the reasons raised in the preceding section and partly because of bona fide needs to expand transportation facilities to serve emerging development in suburban areas, redevelopment in central areas, and general objectives for economic growth.

Clearly, some of the needed investment for infrastructure renewal must come from a reorganization of priorities reflected in total budgets for transportation spending at the expense of investment in system expansion and new facilities.

Spending less on system expansion, however, means using existing facilities more efficiently if user costs are not to increase by unacceptable amounts.

For example, traffic departments in some municipalities often are preoccupied with plans for the construction of new major arterial roads and expressways in established urban areas. Aside from the usual public concerns about this type of system expansion, there are some rather practical economic considerations. New roads and expressways are extremely expensive to construct, particularly from the standpoint of land acquisition. Yet, in many cases, such facilities are proposed to provide additional system capacity while existing facilities continue to be used far below their potential capacity as a result of inadequate parking restrictions, poor enforcement of parking regulations, and outdated methods of traffic control.

Consider the issue of enforcement. When a parked vehicle occupies one lane of a 6-lane arterial road (three lanes in one direction), the capacity of that facility is reduced by approximately one-third, or about 600 to 800 vehicles per hour. Six such occurrences in a general transportation corridor thus deprive the municipality of the same capacity that would be gained by construction of a 6-lane expressway. On an arterial road with only two lanes in each direction, the same vehicle, illegally parked near an intersection so as to interfere with turning movements, reduces capacity by considerably more than one-half. In these examples, the economic trade-offs that are being made involve the costs of parking enforcement and the removal of illegal vehicles versus the cost of building major new facilities. A great deal of enforcement can be purchased for the cost of an expressway, leaving considerable funds for maintenance and rehabilitation.

Diverting Existing Funds From Expansion to Maintenance

Even assuming a high level of enforcement, changes in parking regulations can go a long way to reducing some of the needs for system expansion and allowing the associated funds to be used for accelerated maintenance and rehabilitation. Many municipalities, for example, encourage the concept of staggered work hours to reduce peak demands on facilities (both roads and transit) and spread traffic loads more evenly through a longer peak period. Reducing peak flow obviously reduces peak capacity requirements and can be used as a substitute for new construction.

Usually, however, promotion of staggered working hours or modification of travel demand patterns is not matched by adjustments on the supply side. Thus, some of the worst congestion often occurs at the shoulders of the peak periods, just before and just after parking restrictions come into force. By extending parking restrictions to cover a longer time period, more users will be encouraged to travel in these shoulder periods, thereby reducing the "peak" capacity requirements and the associated investment in new construction. Similar considerations apply to public transit where the size of the vehicle fleet, which represents a major capital investment, could be reduced by spreading peak demands into the shoulder periods.

While these examples may be somewhat trivial, it is equally trivial to propose the construction of expensive new facilities when better methods of transportation system management exist to reduce the need for system expansion. In fact, perhaps only through demonstrations of the ability to use existing infrastructure more efficiently and more intensively can more convincing arguments be made to increase the funding available for maintenance and rehabilitation.

These examples are not intended to suggest that municipal administrators and elected officials should relax their efforts to obtain additional funding. Such efforts may be more successful, however, if a comprehensive approach to the evaluation of maintenance needs and the quantification of the costs of inadequate maintenance is adopted. As noted previously, inadequate attention to maintaining existing road and transit infrastructure is costly for the relevant authorities because of the need for premature and more expensive reconstruction at a later date. However, the added expense of premature reconstruction is only the tip of the iceberg when the user costs of inadequate maintenance are considered. Such costs can be very high during periods of reconstruction. It would be worthwhile, therefore, for transportation authorities to develop benefit-cost analyses that first, reflect total economic costs of inadequate maintenance to the community at large and, second, indicate the increase in agency costs that can be justified by accelerated maintenance programs in terms of overall benefits to users.

CONCLUSION

A number of options deserve consideration in dealing more effectively with the problems of urban transportation infrastructure deterioration that plague most municipalities. These are:

1. Road agencies should assemble information on the life cycle costs and user costs associated with alternative pavement management programs as the basis for justifying needed investment in accelerated maintenance and rehabilitation, using commonly accepted methods of economic analysis.
2. Recognizing the large capital stock in existing infrastructure, methods of evaluation should be developed that can be used to rationalize the allocation of all available funds between maintaining existing infrastructure for current users and system expansion to meet the needs of future users.

3. In established urban areas, where transit services are already extensive, it may be time to redress the balance in favour of more spending on roads.
4. Differential subsidies between road improvements and transit, and between capital and operating costs gradually should be eliminated so that municipal officials can choose among alternative expenditures in terms of the same real dollars.
5. Before committing funds for costly system expansion and capacity increases that could be dedicated to accelerated rehabilitation, measures should be taken to utilize existing infrastructure more intensively through various means of better transportation system management, including traffic control, modified parking policies, and their enforcement, and extension of peak transit service into shoulder periods.
6. Because road deterioration, in particular, can be directly related to traffic density, consideration should be given to earmarking some portion of the fuel taxes generated in urban areas to establish special funds for accelerated maintenance and rehabilitation of urban infrastructure.

PRIORITIES FOR PROVINCIAL SPENDING ON URBAN TRANSPORTATION: AN ONTARIO PERSPECTIVE

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Provincial-Municipal Transportation
Ministry of Transportation and Communications
Toronto, Ontario

ABSTRACT

Changing conditions in urban transportation over the past decade have resulted in changed priorities and directions for the urban transportation programs of the Ministry of Transportation and Communications. This paper reviews the Ministry's infrastructure renewal programs, emphasizing the problems, issues and challenges of the coming years.

Using the greater Toronto area as an example, the paper develops in specific terms the requirements for maintaining and upgrading urban transportation infrastructure, and the funding competition arising from proposed major expansion projects. It concludes by examining the Ministry's current actions and priorities towards achieving desirable levels of transportation infrastructure renewal.

RÉSUMÉ

L'évolution du transport urbain au cours des dix dernières années a fait changer les priorités et l'orientation des programmes de transport urbain du ministère des Transports et des Communications. L'exposé brosse un tableau des programmes de renouvellement des infrastructures entrepris par le Ministère et fait ressortir les problèmes et les défis auxquels il faudra faire face au cours des années qui viennent.

Utilisant la région du Toronto métropolitain comme exemple,l M. Johnston cerne les besoins d'entretien et d'amélioration de l'infrastructure du transport urbain et explique la concurrence que les grands projets d'expansion livrent à ces travaux au plan du financement. Enfin, il examine les activités et priorités actuelles du Ministère en vue de parvenir à renouveler l'infrastructure de la façon souhaitée.

TRAFFIC ENGINEERING AND CONTROL DURING INFRASTRUCTURE RENEWAL

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ABSTRACT

The aging road and bridge infrastructure in most Canadian cities is in dire need of renewal. Although a great deal of concern is being expressed about the financial resources needed to accomplish the required renewal, there is also concern about the cost imposed on the road user by delays and congestion when roads and bridges are being repaired.

This paper deals with the traffic engineering techniques being applied or considered in the Toronto area to minimize the traffic disruption and delay to the road user resulting from the partial or complete road closures at rehabilitation sites.

Two case histories serve as examples of a partial closure in the one case, and a complete road closure in the other case. Comparisons are drawn of the relative costs to each party, the owner of the structure vis-a-vis the road user.

In addition, this paper discusses the need to inform road users adequately of works which may affect their travel patterns, and the consultative process which takes place with the management of major traffic generators in the vicinity of major road and bridge rehabilitation work.

RÉSUMÉ

Les ponts et les routes de nombreuses villes canadiennes se font vieux et ont grandement besoin d'être renouvelés. Or, non seulement faut-il se préoccuper de trouver les moyens financiers requis pour effectuer ce renouvellement, il faut aussi qu'on se soucie des coûts supplémenttaires qu'entraînent le retard et les embouteillages causés par la circulation pendant les travaux de réfection.

L'exposé traite des techniques d'organisation de la circulation employées ou envisagées dans la région de Toronto pour garder au minimum les dérangements et les retards occasionnés par la fermeture patielle où totale des routes, aux endroits ou l'on procède à des travaux de réaménagement.

M. Cass se réfère à deux cas particuliers -- une fermeture partielle et une fermeture totale -- et compare leurs coûts relatifs pour les usagers et les propriétaires de l'installation en voie de réparation. Il discute également de la nécessité de bien informer les usagers de la route des travaux de réparation qui peuvent les faire modifier leur trajet usuel et décrit le mécanisme des principales <<sources>> de circulation dans le voisinage du site où s'effectuent de gros travaux de réaménagement des ponts et chaussées.

INTRODUCTION

Recognition of the need to maintain and renew our urban infrastructure of roads and bridges is slowly but surely being recognized by those who have the authority to assign the necessary money. Preoccupation with the effort to convince the political decision makers to direct the necessary funding toward rehabilitation to some degree has overshadowed concern for the road users who are, in the final analysis, the recipients of the benefits which these facilities provide to the community. Not only do inadequate and improperly maintained roads and bridges add to the cost of travel but, also should repairs go unattended for too long the roads or the bridges may no longer be of service because of their deterioration.

In Metropolitan Toronto there are more than 711 kilometres of arterial roads and expressways within the jurisdiction of the Metropolitan Roads and Traffic Department. There are close to 2 million vehicles travelling on the streets of Metro every day, making an estimated 5 million person trips. More than two-thirds of all of these trips are made on the metropolitan road system. With this density of travel, partial or total closures of any roadway for the purposes of maintenance or rehabilitation creates a severe pressure on the total system in view of the limited capacity available to handle redirected traffic. This results in considerable cost to consumers -- to road users -- because of the added travel time. The total cost of delays, in extra fuel, and frustration, for example, must be considered when rehabilitation of the roads is being planned.

TRAFFIC ENGINEERING AND CONTROL

The traffic engineer must concern himself not only with the reconstruction projects which is principally the responsibility of the maintenance engineer, but with the road user as well. In addition, the traffic engineer also must concern himself with the safety and working environment of those who are doing the road or bridge work. On being apprised of a work program for the rehabilitation of roads and bridges, the traffic engineer must begin immediately to determine how such work can be undertaken in a manner will would provide a safe working environment yet minimize user and owner costs. They must ensure a safe driving environment and provide reasonable access to the fronting properties. In addition, the traffic engineer is responsible for ensuring that the public is adequately notified of the impending closures or partial closures of roadways and bridges, and of the options available for gaining access to their businesses or properties.

During the actual construction, traffic engineers are responsible for:

- placing and maintaining adequate traffic signs to advise the motoring public of the routes to be taken;
- guaranteeing the safety of both road users and workers;
- appling or changing any pavement markings as a result of the work in progress; and
- changing of traffic signal timing which may be required as a result of the redirecting and rerouting of traffic.

SCOPE OF WORK REQUIRED IN THE METROPOLITAN TORONTO AREA

Responsibility for minimizing user cost is made very difficult because of the magnitude of the repairs and rehabilitation required within the Metro area (see Figure l). To maintain the integrity of the road, each kilometre of road must have some work done to it, on average, once every 15 years. With 711 kilometres of road within the jurisdiction of the Roads and Traffic Department, this means that approximately 50 kilometres of road must be under repair each year.

In addition, there are approximately 300 bridges within the jurisdiction of the Metropolitan Roads and Traffic Department. These bridges receive major maintenance at least once every 20 or 30 years. Thus, between 10 and 15 bridges should be receiving some form of major rehabilitation each year.

In addition to the 50 kilometres of roads and 10 to 15 bridges which are being repaired, of major concern to the travelling public is the Frederick G. Gardiner Expressway, which is an elevated structure for a considerable length having spans

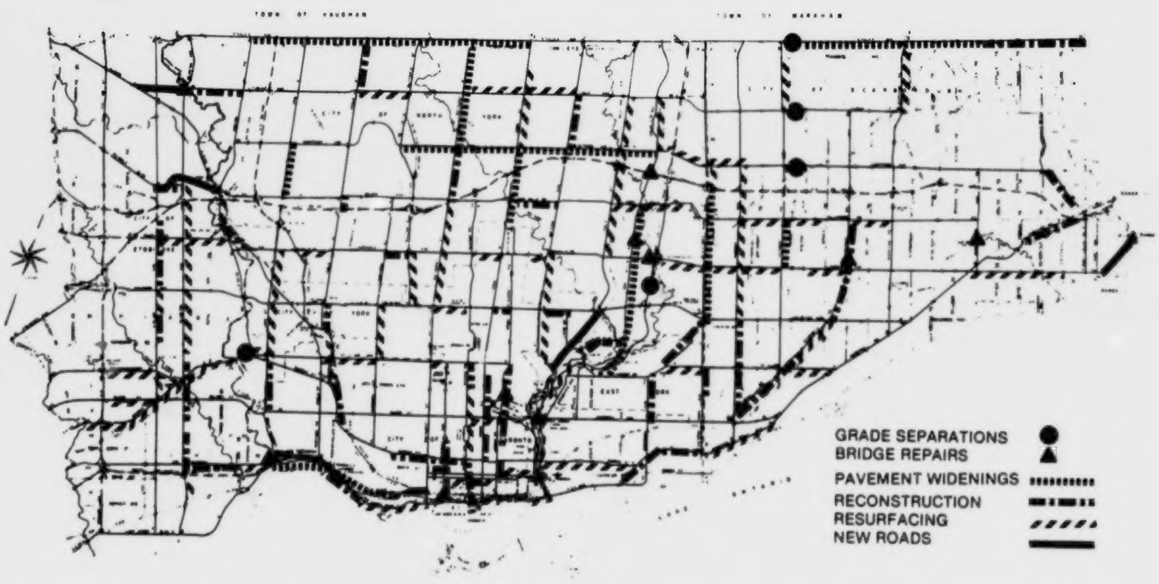

TOWN OF VAUGHAN
TOWN OF MARKHAM
GRADE SEPARATIONS ●
BRIDGE REPAIRS ▲
PAVEMENT WIDENINGS
RECONSTRUCTION
RESURFACING
NEW ROADS

Fig. 1: 1987-1991 METROPOLITAN TORONTO CAPITOL WORKS PROGRAMME

equivalent in length similar to another 300 bridges. The Gardiner Expressway has been the subject of a very comprehensive examination and analysis regarding its needs for rehabilitation. It was determined that a 20-year cycle of work costing about $80 million would be required to restore the elevated portion.

Replacement of the deck over a 6-year period, and rehabilitation of the columns and bents and undersides over the 14 years following the replacement of the deck is being planned. With the announcement of this 20-year program, The Toronto Star on September 15, 1986 reported the matter with bold headlines saying "Gardiner Drivers Face Six Years of Chaos". The article goes on to say, "That more than two-hundred-thousand drivers who use the Gardiner Expressway each week day face six years of chaos if an 82 million dollar rebuilding plan is approved. Since other downtown roads may be torn up at the same time, traffic implications will be quite severe". That is what The Toronto Star had to say, but how bad will it really be? Whether we have chaos or merely extreme difficulties will depend upon the success or failure of traffic engineers in carrying out their responsibilities.

The Metropolitan Toronto area has some unique problems compared to other urban jurisdiction. Because of high volumes on the roads, the displaced traffic would have difficulty finding residual capacity on adjacent roads. For example the 160,000 to 200,000 vehicles per day that travel on the Frederick G. Gardiner Expressway, if totally displaced, would find that it is impossible to divert to roads with sufficient residual capacity for such large volumes. (see Figure 2). On other arterial streets, because of street car operation and trolley bus operation, again there is great difficulty in redirecting the traffic, particularly the transit vehicles. In addition, the utility work which involves Bell Telephone, Consumers' Gas, Hydro, water and sewers, create 10,000 cuts in the pavement each year, which adds to the dislocation of traffic on the Metro road system.

In 1986, the pavement reconstruction and resurfacing program on Metro roads costs $26 million and affected 45 kilometres of roads consisting of an area of 660,000 square metres. To do this job required 37,000 tonnes of crushed stone and 47,000 cubic metres of concrete, as well as 65,000 tonnes of asphalt.

CASE HISTORY 1

To illustrate the process that traffic engineers must undertake to achieve the various goals outlined for a rehabilitation program, a case history of the rehabilitation of a portion of the Frederick G. Gardiner Expressway deck, which was undertaken in 1984 and 1985, will help to demonstrate the various considerations and necessary. This rehabilitation program involved the construction of a new road deck, replacement

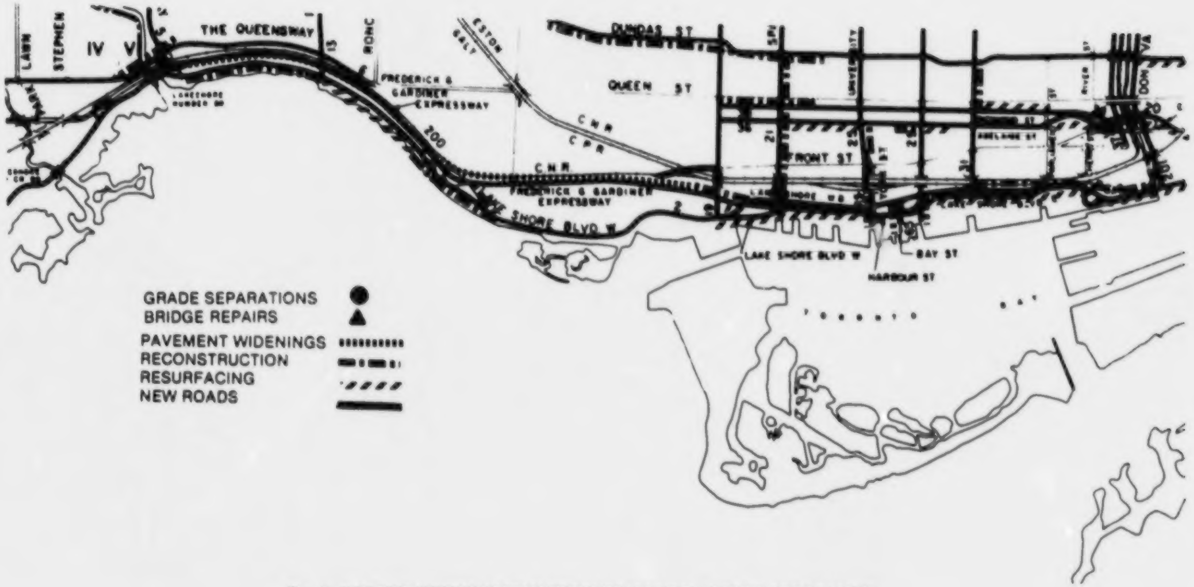

LAWN
STEPHEN
IV
V
LAKESHORE
THE QUEENSWAY
RONC
FREDERICK G. GARDINER EXPRESSWAY
200
ESTON
GALT
C N R
C P R
DUNDAS ST
QUEEN ST
FRONT ST
SPA
UNIVERSITY
RIVER ST
DON VA
C.N.R.
FREDERICK G. GARDINER EXPRESSWAY
LAKE SHORE BLVD W
LAKE SHORE BLVD W
BAY ST
HARBOUR ST
TORONTO BAY
GRADE SEPARATIONS ●
BRIDGE REPAIRS ▲
PAVEMENT WIDENINGS
RECONSTRUCTION
RESURFACING
NEW ROADS

Fig. 2: 1987-1991 METROPOLITAN TORONTO CAPITOL WORKS PROGRAMME
LAKE SHORE CORRIDOR

of expansion joints, and resurfacing of the expressway between York and Jarvis Street.

The first order of business for traffic engineers was to hold several meetings with the design and project engineers to determine precisely what physical works had to be undertaken and in what sequence. The objective of these meetings was to determine whether it was possible to undertake the necessary works and still maintain traffic flow on the expressway. The traffic engineers already had ascertained that the week-day traffic flow was such that a total diversion would be impractical, and therefore, they had to devise ways of achieving some degree of traffic flow on the expressway during the construction period.

As a result of these meetings, the traffic engineers determined that for the sake of safety, the construction area had to be extended from the Spadina off-ramp to the Don Valley Parkway. Although this extended the total work area behond what was absolutely essential, the need for providing a reasonable opportunity for traffic to be accommodated safely dictated this decision. The traffic engineers determined that it would be possible to maintain four of the six lanes at all times, so that only two lanes are under construction. They also determined that both the Leslie Street ramp to the westbound Gardiner, and the Rees Street ramp to the eastbound Gardiner should be closed to the public.

They further determined that in order to provide a safe working environment for the labourers, a speed reduction from 90 km per hour to 60 km per hour through the construction area was required. They also proposed that temporary concrete barriers be used to separate opposing traffic flows and, also, to separate the work zone from the travelled portion of the expressway.

The need to relocate the barriers as each pair of lanes was completed required five weekend total closures of the Gardiner Expressway. During each closure, the barrier walls were relocated, line painting on the pavement was changed, all other traffic signing necessary was changed, and other safety measures were undertaken. This resulted in four phases during which a different pair of lanes were cut off for reconstruction purposes.

The traffic engineers compared the cost of doing the work with total closure to the program they had proposed. They discovered that the total rehabilitation would cost approximately $3.8 million in either case. The only savings, therefore, would be in the traffic control measures, which would have to be undertaken during the partial closure process. As it turned out, the costs for these traffic control measures, which required signs, line painting, temporary barriers, and many other similar features, added up to a total of $713,000.

The other costs that had to be considered were the user costs for partial closure compared to complete closure. In this regard the traffic engineers determined that the work could be done within 6 months if the road were totally closed; and 16 months if partially closed. In this particular case, however, the choice was academic, since no adequate alternative capacity was available to accommodate a complete closure. One readily can see, though, that should a condition arise whereby it would be possible to redirect the traffic from the work zone, a complete closure would be the more cost-efficient alternative.

The next function that traffic engineers had to undertake was the public relations function, that is notifying the adjacent land users who would be adversely affected by the construction program, as well as the general motoring public. A series of meetings were arranged with representatives of the Canadian National Exhibition, Ontario Place, The Jockey Club, and other organizations whose activities along the Lake Shore area would be adversely affected. Similar meetings were held with the Toronto Fire Department, the Ambulance Department, and the Police Department. Other meetings were held with the TTC and Go Transit. It was obvious that these organizations were unhappy with the traffic problems that would be created during the period of reconstruction because it impinged on freedom of access to their properties and activities which, in turn, could reduce the profitability of their undertakings.

To assist in the program of notification to both local land users and the public, a brochure was published showing the four phases of the rehabilitation program, giving the estimated dates during which these phases would apply and describing as well as possible the manner in which access would be maintained (see Figures 3 through 6). This brochure was distributed to radio and TV stations and the press so that they, in turn, could notify their audiences of the activities that would be taking place in this area.

Another important activity that the traffic engineers had to undertake was a series of meetings with the public utilities who might have been planning various works in the general area affected by this closure. Similar meetings were held with the City of Toronto Works Department and the design and project engineers of the Metropolitan Roads and Traffic Department to ensure that other roads that would be required to accommodate the detoured traffic would not simultaneously be affected by their works.

As a result of the time devoted to such meetings, the detailed explanations given to the media and the careful planning of maintenance of the traffic flow, there was a reasonably smooth operation of traffic during the period of rehabilitation. Of course, there were delays, frustration, and unhappiness, but their degree was considered by all to be within tolerable limits.

F.G. GARDINER EXPRESSWAY
CONCRETE DECK REHABILITATION 1984-85
PHASE I (APRIL 1984)

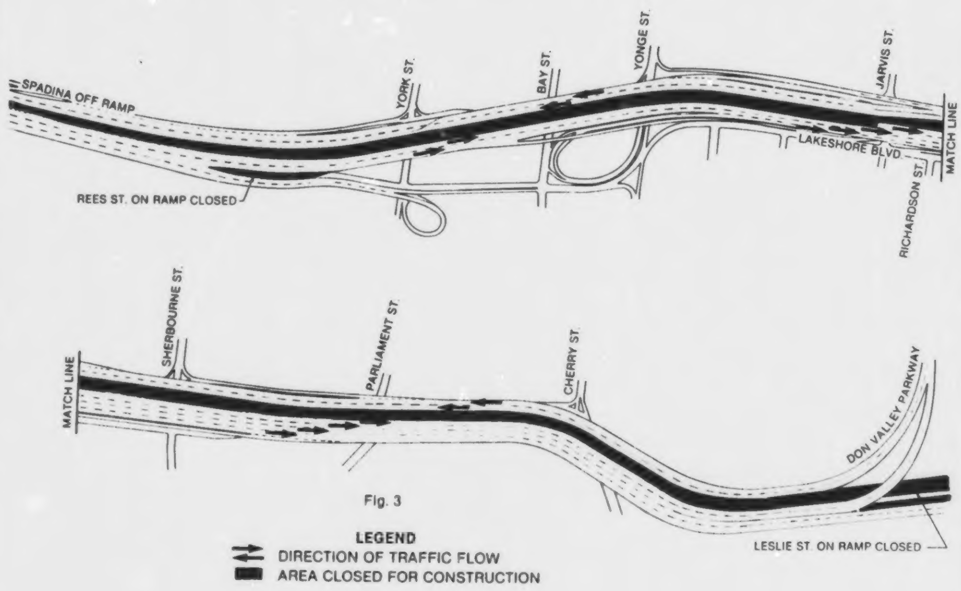

SPADINA OFF RAMP
YORK ST.
BAY ST.
YONGE ST.
JARVIS ST.
MATCH LINE
LAKESHORE BLVD
RICHARDSON ST.
REES ST. ON RAMP CLOSED
MATCH LINE
SHERBOURNE ST.
PARLIAMENT ST.
CHERRY ST.
DON VALLEY PARKWAY
LESLIE ST. ON RAMP CLOSED
LEGEND
⇄ DIRECTION OF TRAFFIC FLOW
▬ AREA CLOSED FOR CONSTRUCTION

Fig. 3

MUNICIPALITY OF METROPOLITAN TORONTO DEPARTMENT OF ROADS AND TRAFFIC

F.G. GARDINER EXPRESSWAY
CONCRETE DECK REHABILITATION 1984-85
PHASE II (MAY 1984 - JULY 1984)

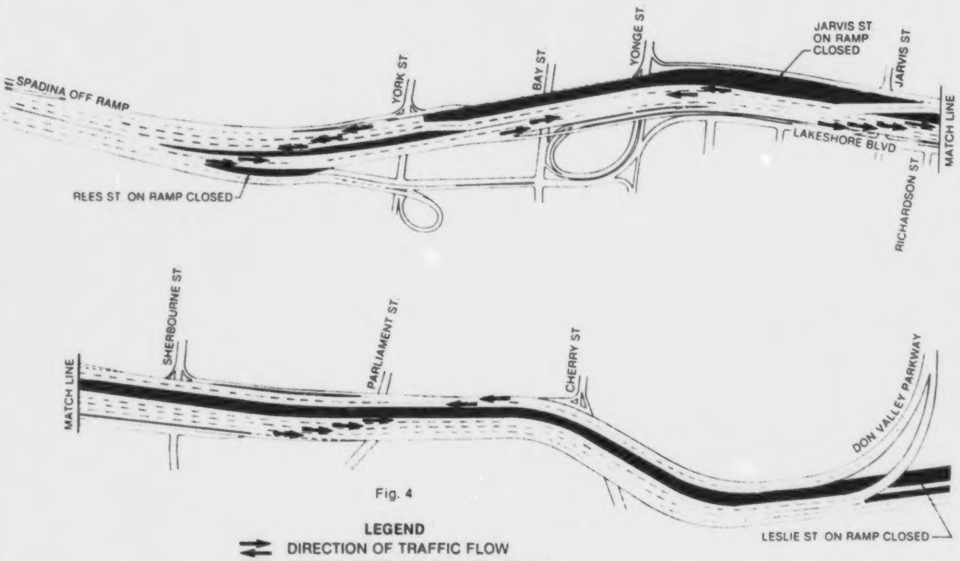
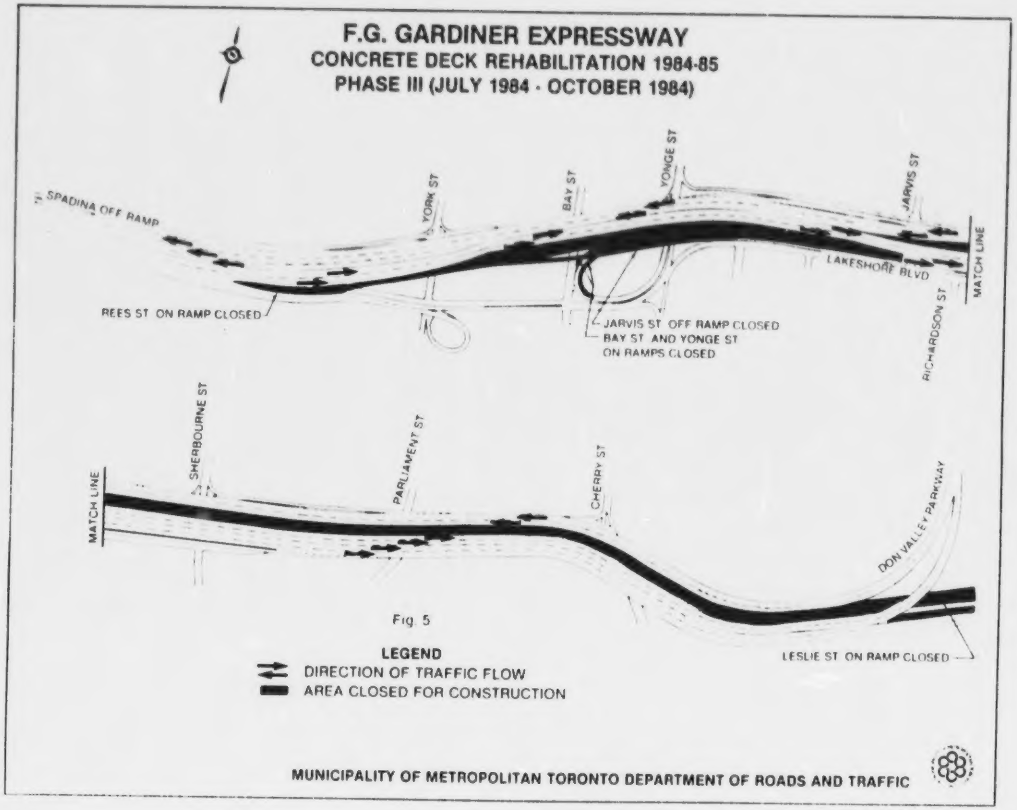

SPADINA OFF RAMP
YORK ST
BAY ST
YONGE ST
JARVIS ST ON RAMP CLOSED
JARVIS ST
MATCH LINE
LAKESHORE BLVD
RICHARDSON ST
REES ST ON RAMP CLOSED
MATCH LINE
SHERBOURNE ST
PARLIAMENT ST
CHERRY ST
DON VALLEY PARKWAY
LESLIE ST ON RAMP CLOSED

Fig. 4

LEGEND
- ⇄ DIRECTION OF TRAFFIC FLOW
- ▬ AREA CLOSED FOR CONSTRUCTION

MUNICIPALITY OF METROPOLITAN TORONTO DEPARTMENT OF ROADS AND TRAFFIC


F.G. GARDINER EXPRESSWAY
CONCRETE DECK REHABILITATION 1984-85
PHASE III (JULY 1984 - OCTOBER 1984)

SPADINA OFF RAMP
YORK ST
BAY ST
YONGE ST
JARVIS ST
MATCH LINE
LAKESHORE BLVD
RICHARDSON ST
REES ST ON RAMP CLOSED
JARVIS ST OFF RAMP CLOSED
BAY ST AND YONGE ST ON RAMPS CLOSED
SHERBOURNE ST
PARLIAMENT ST
CHERRY ST
DON VALLEY PARKWAY
MATCH LINE
LESLIE ST ON RAMP CLOSED
LEGEND
⇄ DIRECTION OF TRAFFIC FLOW
▬ AREA CLOSED FOR CONSTRUCTION
MUNICIPALITY OF METROPOLITAN TORONTO DEPARTMENT OF ROADS AND TRAFFIC

Fig. 5

F.G. GARDINER EXPRESSWAY
CONCRETE DECK REHABILITATION 1984-85
PHASE IV (OCTOBER 1984 - JULY 1985)

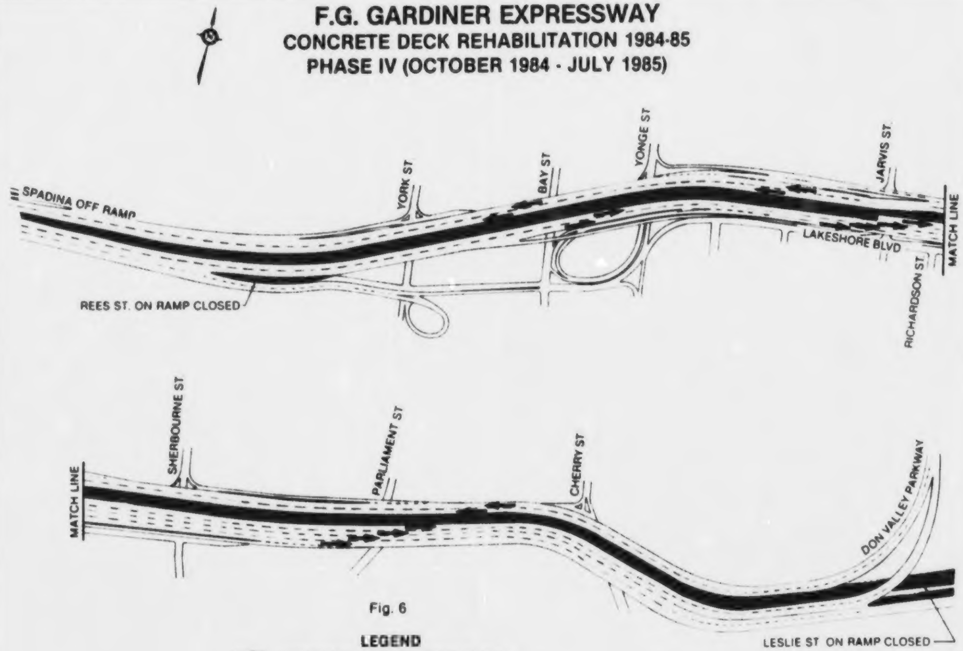

SPADINA OFF RAMP
YORK ST
BAY ST
YONGE ST
JARVIS ST
LAKESHORE BLVD
RICHARDSON ST
MATCH LINE
REES ST. ON RAMP CLOSED
MATCH LINE
SHERBOURNE ST
PARLIAMENT ST
CHERRY ST
DON VALLEY PARKWAY
LESLIE ST ON RAMP CLOSED

Fig. 6

LEGEND
⇄ DIRECTION OF TRAFFIC FLOW
■ AREA CLOSED FOR CONSTRUCTION

MUNICIPALITY OF METROPOLITAN TORONTO DEPARTMENT OF ROADS AND TRAFFIC

CASE HISTORY 2

In another case history, a major piece of work on an arterial street was required. This case history concerns the lower part of Bay Street south of Front Street. In general, the consideration of major works on arterial streets is much more complex due to the need to maintain accessibility for local businesses, pedestrians and other local activities, as well as the greater difficulties in rerouting traffic to adjacent streets.

The role of traffic engineers in such cases begins very early in the planning of the project. What traffic engineers must examine includes a review of scheduling options for the project and their related costs, as well as information regarding other roadway and utility works in the downtown area scheduled to proceed during the proposed period of the project. They have to analyze all other alternative routes within the immediate vicinity of the project in order to determine their capacity, and the ability of the system to accommodate traffic displaced from the street subject to rehabilitation. Traffic engineers also must identify likely trouble spots and advise what measures can and should be taken to minimize the effect of the closure or partial closure of the street. And finally, the traffic engineers must determine the need to maintain access to properties along the frontage which is required for the regular business and the normal activities within the properties.

Alternative Construction Schedules

Five construction schedules in all were considered. The first was a full closure, which it was estimated would take 13 or 14 months to complete, based on no double shifts and no overtime. As a variation of the total closure, a partial closure was considered, which would have permitted some traffic to flow at all times or, conversely, the road to be open partially at various periods throughout the construction period. This would have caused the project to take anywhere from 17 to 20 months to complete. It also would have increased the costs by approximately $2 million, which represented an increase of between 10 and 15 %.

The next option called for full closure, but by using double shifts, would have reduced construction time to 11 or 12 months, while adding $750,000 to the cost.

The fourth option was a partial closure, but using double shifts to reduce the time necessary for the job to between 15 and 18 months. This would have cost $2.75 million more.

The final option would be a full closure, but using double shifts and overtime to reduce the time of construction to 9 or 10 months. This would add approximately $1 million to the base cost.

The traffic engineers are opting for a complete closure which may appear to be counter-intuitive, but is based on the opinion that the downtown road system can continue to function at a reasonable level of service during the construction, provided a permanent shift in vehicular traffic travel patterns throughout the construction period can be achieved. Achievement of such a shift is best accomplished by means of a full closure because once regular downtown drivers know that Bay Street is closed, they will seek alternative routes. If, however, Bay Street is kept partially open, then many drivers will take their chances, so to speak, and attempt to use it. The result will likely be that more drivers will attempt to use Bay Street through the construction area than there is available capacity to accommodate them. Furthermore, if Bay Street is fully closed, then various intersections in the area could be more confidently redesigned, as far as their traffic signal timing is concerned, to accommodate the additional load caused by the shift in travel patterns.

Adjacent Property Access

Traffic engineers were required to inventory and inspect all properties immediately adjacent to the proposed construction zone which had vehicular access from Bay Street, and take traffic counts were taken. Proposals had to be drafted by the traffic engineers regarding modifications to the work program to ensure that regardless of the final decision for total or partial closure of the work zone, access to the individual properties will be maintained through all or most of the construction program.

It also was necessary to determine the need for pedestrian passage through the construction zone. Alternative routes for pedestrians were almost impossible in this case and, therefore, pedestrian passage through the work zone was required throughout the whole program of work.

Reassignment of Traffic

An examination had to be made of the residual traffic capacity on all adjacent streets within the immediate area, and on other nearby streetsthat would be affected by the reassigned traffic. First traffic originating from or destined to properties adjacent to the construction zone was reassigned to streets immediately adjacent to Bay Street. The remaining traffic, which was considered to be non-local, then was assigned to other streets further afield.

In the process of reassigning traffic volumes displaced from Bay Street, additional traffic management strategies were developed. For example, opportunities were identified for:

- increasing the capacity of particular movements on other streets through operational improvements such as the introduction or extension of advanced green signal phases at key intersections, placing alternate route signage and notices of the Bay Street closure and assigning point duty police officers at some locations; and

- recommending parking and stopping prohibitions along critical sections within the study area and identifying locations where physical improvements could be implemented on a temporary basis.

Other Road Construction Projects

An inventory was taken of all the planned road works within the vicinity of Bay Street that would be underway during the Bay Street closure or partial closure. These works were weighted in accordance with the severity of disruption they would cause to the road system in the vicinity of Bay Street. Some of the planned road works were rescheduled. It was determined that if the Bay Street construction could be kept to a 12-month period, begun no earlier than May, 1987, and completed no later than May or June, 1988, that the other works could be done in 1987, prior to the closure of Bay Street and in 1988, following the reopening of Bay Street.

TRAFFIC ENGINEERING DURING A CONSTRUCTION PROJECT

As can be seen from the case histories, the traffic engineers' role in project planning is very extensive and has a great bearing on the manner in which the project will be undertaken. With respect to the Bay Street project, those decisions have as yet to be finalized, but the data for the project and its impact on traffic are being collected and will figure prominently in the final decisions.

When a project does begin, the traffic engineers' role is not completed, for they must monitor the traffic flow in the vicinity of the work and fine-tune the operational controls and regulations, including traffic signal timings. They must ensure that the appropriate diversionary and warning signs are all in place, and that the greatest safety for the workers and the public is maintained while attempting to squeeze the maximum capacity out of the street system during the construction project.

BALANCING NEW ROAD CONSTRUCTION WITH ROAD MAINTENANCE NEEDS

R. J. McRae
Works and Operations
City of Winnipeg, Manitoba

ABSTRACT

That funding is inadequate for the proper maintenance and rehabilitation of urban road systems is a recognized reality. In formulating pavement renewal programs where work on all candidate projects cannot be funded, administrators must expand their decision-making process in order to be fully cognizant of the impact of a particular rehabilitation measure on the future condition of a given pavement section and on the overall condition of the road system.

Detailed information is needed on pavement condition, construction history, and other decision-making data; and it must be possible to retrieve and analyze the data so that valid rehabilitation alternatives for a project can be determined, along with their respective life-cycle costs and benefits, so that an optimum pavement renewal program can be established. This decision-making process is a component of a pavement management system.

This paper contains a case history outlining the application of the APWA-COE PAVER pavement management system methodology in developing a rehabilitation program for the Assiniboine Park road system in the City of Winnipeg.

RÉSUMÉ

Il est reconnu que les fonds affectés à l'entretien et au réaménagement des réseaux routiers ne sont pas suffisants pour permettre de faire du bon travail. Les administrateurs doivent donc perfectionner leur mécanisme de prise de décision de façon à pouvoir connaître tous les effets des travaux de réaménagement envisagés sur l'état à venir d'une section donnée de la chaussée, ainsi que les répercussions du choix d'un mode de réaménagement particulier sur l'état du réseau routier dans son ensemble.

Pour cela, il faut recueillir des données détaillées sur l'état de la chaussée, la façon dont elle a été construite et divers autres aspects; il faut aussi pouvoir avoir accès à ces données et à ces renseignements pour faire des recherches documentaires et des analyses. Alors seulement pourra-t-on cerner les solutions de réaménagement valables pour un projet donné et établir leurs coûts et avantages respectifs à long terme. Ce mécanisme de prise de décision, qui est un élément clef de la gestion des chaussées, permet d'établir un programme de renouvellement optimal.

M. McRae se réfère au cas du réseau routier du parc Assiniboine, à Winnipeg, pour illustrer l'utilisation de la méthode de gestion des chaussées APWA-COE PAVER pour établir un programme de réaménagement.

INTRODUCTION

In 1984, a task force established by the Federation of Canadian Municipalities (FCM), which represents most of the larger cities and towns in Canada, conducted a study (1) to ascertain, in part, both the physical status of urban infrastructure and the adequacy of funding.

The study findings indicate that in terms of the present condition of urban infrastructure facilities, roads and sidewalks are in greatest need of repair. While most other infrastructure facilities were reportedly improved in condition over the past 15 years, roads were a significant exception, with 48% of respondents believing that the condition of road systems had worsened. The estimated cost of bringing road systems to an acceptable level is high, with 40% of the total funding required to improve urban infrastructure facilities being spent on roads. Funding shortages were ranked by respondents as the overwhelming impediment to the successful rebuilding and protection of urban infrastructure.

The selection of rehabilitation programs for a road system must be developed on the basis of priorities determined under budget constraints, with the objective of achieving the best overall value with available funds. The development of optimum rehabilitation programs requires answers to the following questions:

1. What are the rehabilitation needs for the road system over a selected program period?
2. What prioritization strategies are most effectively assigned to these needs?
3. How do available budgets affect the effectiveness of these strategies?

Candidate rehabilitation projects must be identified based on thorough evaluation of existing pavement sections. Candidates for rehabilitation are those existing sections predicted to reach a minimum desirable condition level for a rehabilitation technique within the program period. The best rehabilitation alternative for each project can be determined based on life-cycle cost analyses and benefit analyses associated with each rehabilitation measure.

In determining a prioritization strategy to meet the rehabilitation requirements of each project, the effectiveness of various strategies can be determined from the impact of each program strategy on the overall condition level of the road system and on the costs associated with employing each strategy.

The effectiveness of each priority program strategy is a function of the annual budget funds available for rehabilitation. Depending on the priority strategy, rehabilitation projects are planned for implementation in the year in which they offer maximum benefits. When anticipated budgets are insufficient to complete all projects in their optimum benefit year, projects must be deferred. Under this constraint, priority strategies must be evaluated so that the strategy which offers maximum improvement to the overall condition level of the road system at the minimum cost, within identified budget constraints, is selected.

To develop and analyze these strategies requires the assembly and rapid retrieval of data on the existing road system, and the capacity to make valid predictions of pavement deterioration based on this data. A systematic method for the collection, storage and retrieval of this decision-making information is needed, as well as a set of procedures for quickly manipulating the information and carrying out analyses to arrive at the decisions required to make maximum use of available budget dollars. This is the concept behind a pavement management system.

One of many available pavement management systems is the APWA-COE PAVER pavement management system.

PAVER was developed by the United States Army Corps of Engineers' Construction Engineering Research Laboratory for streets and paved areas at army installations, and has been adapted for city and country use by the American Public Works Association (2).

PAVER'S capabilities include data storage and retrieval, pavement network definition, pavement condition rating, project prioritization, determination of present and future pavement condition, determination of repair needs, performance of economic analyses and benefits assessment, and budget planning.

PAVER is currently being implemented by the City of Winnipeg on its arterial, collector, and residential street network. Prior to implementing PAVER, its capabilities in improving the efficiency of selecting optimum rehabilitation programs strategies were assessed by applying the PAVER methodology to a study of the Assiniboine Park road system.

The following case history outlines the application of PAVER's decision-making procedure for identifying cost-effective repair programs.

ASSINIBOINE PARK ROAD STUDY

The Assiniboine Park is a 115 hectare facility located in the southwest area of the City of Winnipeg. There are many attractions in the Park, including the Assiniboine Park Zoo, the Conservatory's indoor Palm House and Display Garden, outdoor floral gardens, cricket and field hockey areas, and picnic areas. These facilities are accessed by a 14 lane-kilometre road system (Figure 1) which has been developed and expanded since the park was opened in 1903 to the point where over 650,000 vehicles travelled over the road system in 1985.

The park road system last received a major upgrading in 1964 and 1965. In this 2-year period, all roads were reconstructed as asphalt pavements, where previously they had been gravel or oil-treated.

In the interim period to 1984, the road system received routine maintenance. Some pavement sections received thin asphalt overlays in a period from 1971 to 1973. In 1984, the road system had reached the point where major maintenance was required. A study was undertaken to determine the condition of the existing road system and to define a restoration program.

Road System Definition

For the purpose of carrying out the study, and in accordance with PAVER methodology, the road system was divided into sections. These sections were defined based on structural composition, construction history, maintenance history, and ease of isolating the sections to carry out individual rehabilitation projects with minimal inconvenience to park users.

Pavement Condition Ratings

Pavement condition ratings provide the means to monitor pavement deterioration and establish the cause of the deterioration (load- or climate-related). The condition rating process for the Assiniboine Park road system included systematic evaluation of distresses observed on the pavement surfaces and deflection testing of each pavement section's load-carrying capability.

A detailed pavement condition survey was carried out on each pavement section using the PAVER field manuals to arrive at a pavement condition index. Each pavement section was further divided into sample units of approximately 230 square metres in area. A number of representative sample units were inspected and the distress measures of these samples were extrapolated to determine a condition rating for the entire section.

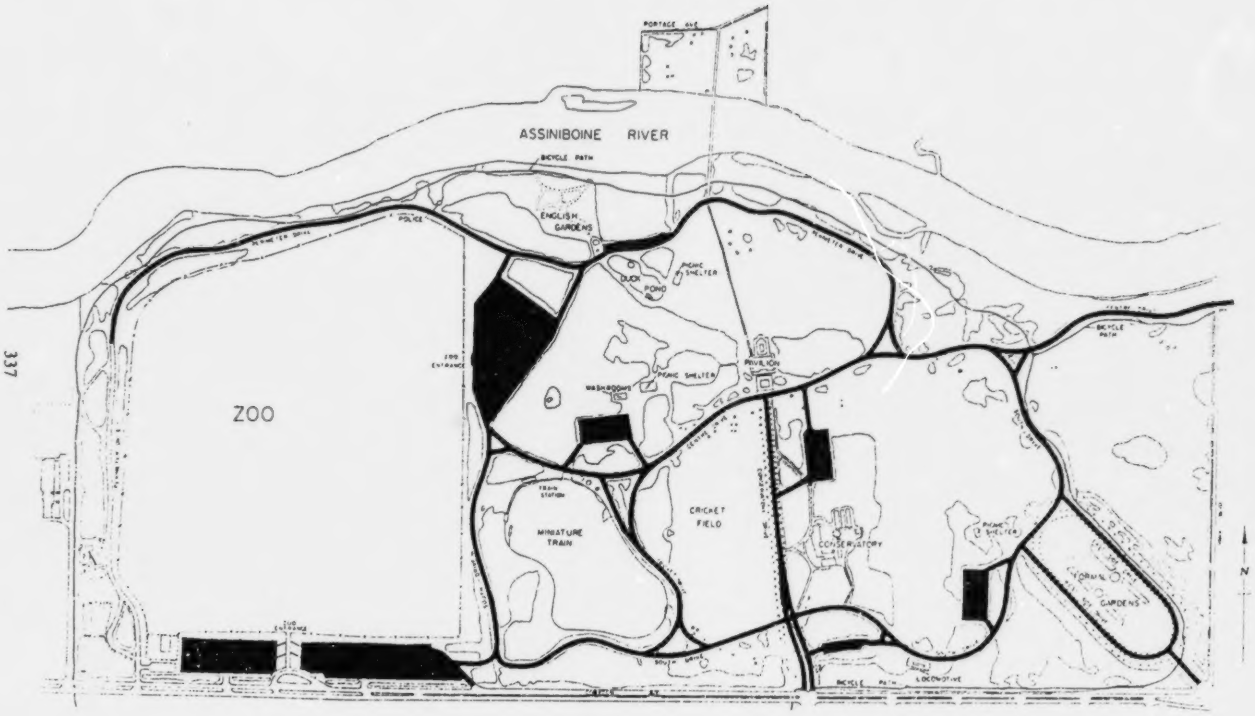

PORTAGE AVE
ASSINIBOINE RIVER
BICYCLE PATH
ENGLISH GARDENS
POLICE
PERIMETER DRIVE
DUCK POND
PICNIC SHELTER
PAVILION
ZOO ENTRANCE
WASHROOMS
ZOO
TRAIN STATION
MINIATURE TRAIN
CRICKET FIELD
CONSERVATORY
FORMAL GARDENS
ZOO ENTRANCE
SOUTH DRIVE
LOCOMOTIVE
N

Fig. 1. ASSINIBOINE PARK ROADS AND PARKING LOTS

The PAVER condition survey is an objective, systematic, repeatable means of measuring observable pavement distresses, which in turn relate to pavement condition. In addition to identifying the type of distress, the severity of each distress (width of cracks, depth of ruts, etc.), and the density of each distress (a percentage of the sample unit area) are recorded. From this information, a pavement condition index (PCI), ranging from 0 to 100, can be calculated. The PCI values relate to a "failed" rating for PCI's less than 10 up to an excellent rating for PCI's over 85. The results of the condition survey are shown in Figure 2.

The structural adequacy of each pavement section was determined by deflection testing using the Benkelman beam. The results of this testing were used to determine overlay thickness requirements when considering alternative rehabilitation strategies.

Traffic Data

Traffic counts were carried out on each pavement section. This information, used in conjunction with available tour bus and truck data, formed the basis for pavement designs when considering reconstruction alternatives.

"As-Built" Records

A key element to diagnosing problems and designing rehabilitation solutions is knowing when and how the pavement was originally constructed and what has been added since. This historical data provides a base from which PAVER initially determines the rate of deterioration, in PCI points per year.

The rate of deterioration, as well as prediction of future condition, are based on a straight line extrapolation method. An example is shown in Figure 3. The slope of a straight line between the condition index at the last major rehabilitation (PCI = 100) and the PCI at the last inspection date represents the rate of deterioration. This line is extrapolated to predict future PCI's. While considered a crude measure of deterioration, as most pavement deterioration curves are not linear, this method does provide a reasonable prediction of short-term deterioration (up to 5 years).

Condition Evaluation Results

Results of the pavement condition survey (Figure 4) indicate that 67% of the road system was in poor or worse condition. Using the aforementioned technique for predicting deterioration of a pavement section, it was determined that, without any change in the current level of maintenance, the number of pavements in poor or worse condition would increase to 83% within the next 5 years, with almost half of the

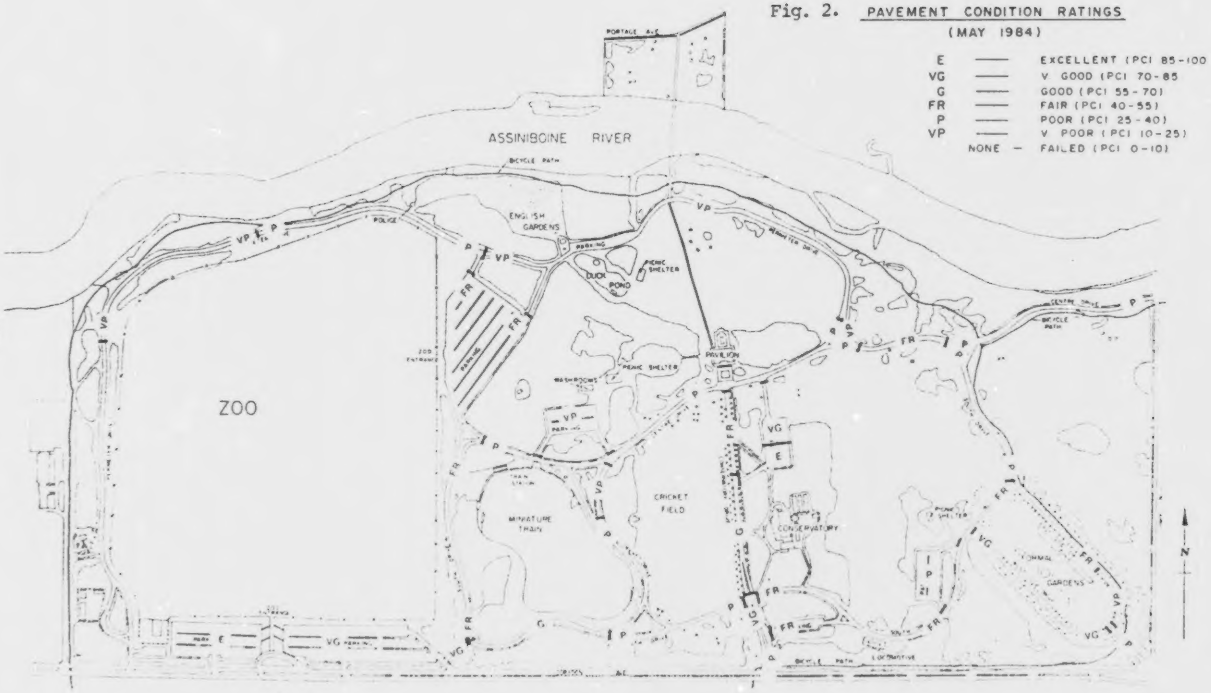


Fig. 2. PAVEMENT CONDITION RATINGS (MAY 1984)

E — EXCELLENT (PCI 85-100)
VG — V GOOD (PCI 70-85)
G — GOOD (PCI 55-70)
FR — FAIR (PCI 40-55)
P — POOR (PCI 25-40)
VP — V POOR (PCI 10-25)
NONE – FAILED (PCI 0-10)
PORTAGE AVE
ASSINIBOINE RIVER
BICYCLE PATH
POLICE
ENGLISH GARDENS
PARKING
DUCK POND
PICNIC SHELTER
ZOO ENTRANCE
ZOO
PAVILION
WASHROOMS
TRAIN STATION
MINIATURE TRAIN
CRICKET FIELD
CONSERVATORY
FORMAL GARDENS
LOCOMOTIVE
CENTRE DRIVE
N
E
VG
G
FR
P
VP
21

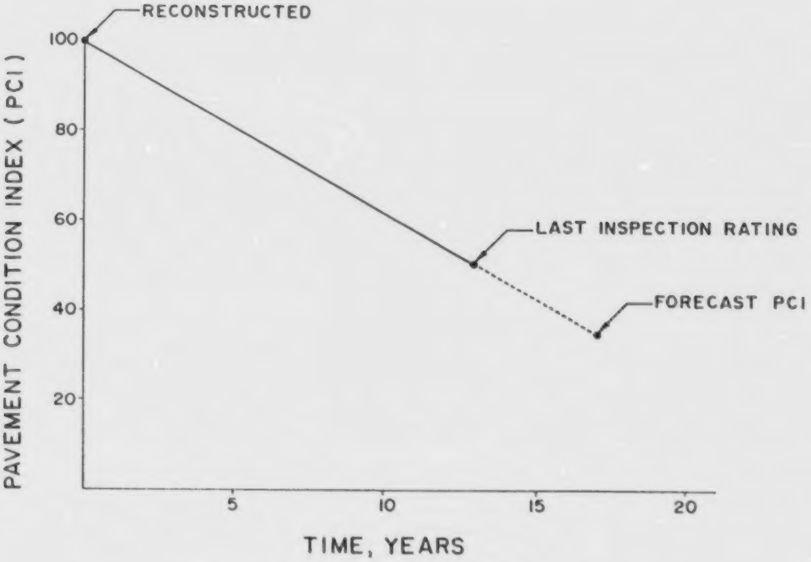


Fig. 3. Illustration of Straight Line Forecasting Techniques

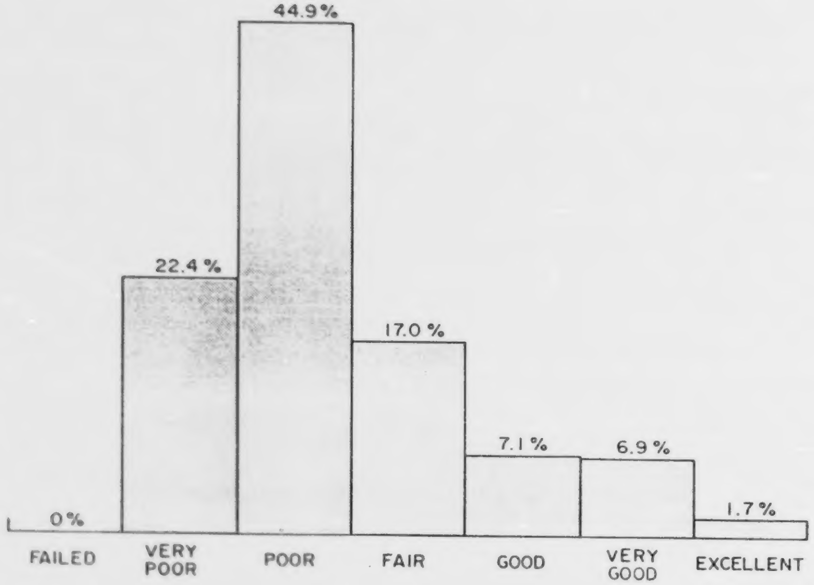


Fig. 4. Current Pavement Condition of Park Roadways
(Percentage of total area)

pavement sections deteriorating to a "failed" condition (Figure 5). Immediate measures were required to reverse the deteriorating level of the park road system.

Rehabilitation Alternatives for Single Sections

Depending on the condition of each section, one or more of the following rehabilitation strategies were considered:

1. patching;
2. nominal thickness asphalt overlays, typically equal to half the thickness of a structural asphalt overlay, on pavements with low rates of deterioration, with patching as required;
3. structural asphalt overlays of from 100 mm to 150 mm thickness, with patching as required;
4. staged asphalt overlays, where half the thickness of a structural overlay is placed with patching, and a second overlay of equal thickness placed at a later date while the first overlay was still in good condition (PCI greater than 70), thereby allowing the combined thickness to act as a structural overlay; and
5. reconstruct a new asphalt pavement.

For each pavement section, the costs and effectiveness of each alternative were evaluated using PAVER's economic analysis and benefit assessment computer programs.

Economic Analyses

For economic analysis, PAVER's computer program considers life-cycle costing; that is, the original cost of the rehabilitation alternative and its related maintenance requirements. This analysis reports the original cost of each alternative, the present worth of the alternative, and the equivalent uniform annual cost (EUAC) of the alternative. (An example is given in Table 1.)

Benefit Analyses

For benefit analyses, PAVER's computer program computes benefits in non-monetary units. To be of any benefit, a rehabilitation measure must be capable of raising the condition level of the pavement above a minimum desirable level. The benefit program computes the performance area under a PCI time curve, bounded by the minimum desirable PCI (Figure 6). The shaded areas for the example in Figure 7 represent the performance areas for the various alternatives. The larger the per-

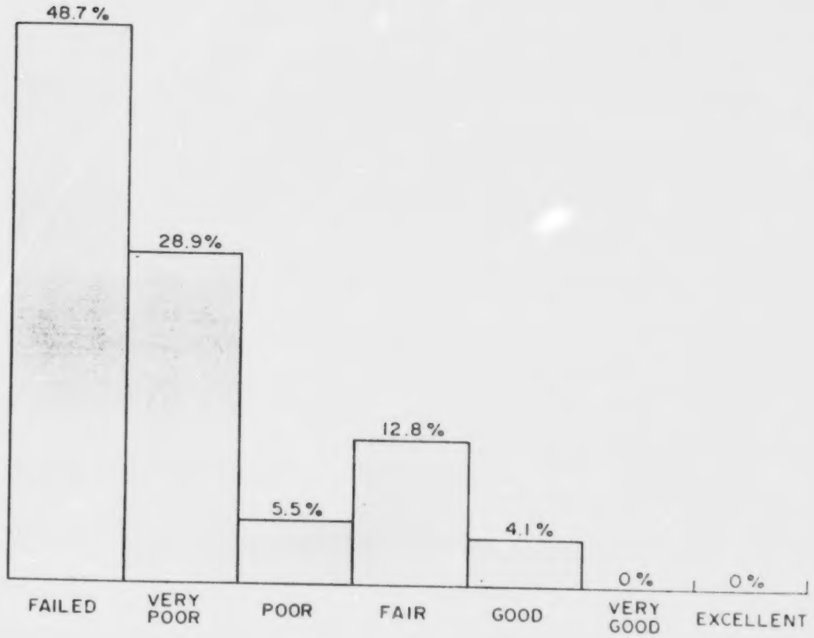


Fig. 5. Pavement Condition of Park Roadways in Five Years (1989) With Current Level of Maintenance
(Percentage of total area)

TABLE 1

Centre Drive From Conservatory Drive to Cricket Drive
Economic Analyses Of Rehabilitation Alternatives

	Cost
Alternative 1	
Reconstruction	69,600
Crack Sealing and patching every 5 years	2,000
Alternative 2	
75 mm Overlay and patching	43,800
Crack sealing and patching every 5 years	2,000
Alternative 3	
Crack sealing and major patching	13,400
Crack sealing and patching every 3 years	2,000

	Alternatives		
	1	2	3
Initial Cost	69,000	43,800	13,400
Present Value	74,180	47,304	16,935
Equivalent Uniform Annual Cost	8,713	7,324	3,479
EUAC/m2	5.35	4.50	2.13

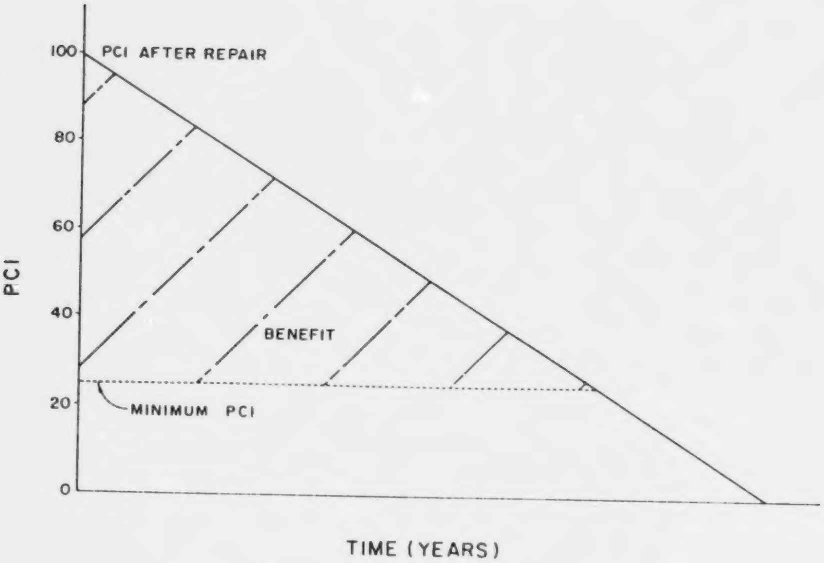


Fig. 6. Definition of Benefit (or Performance Area)

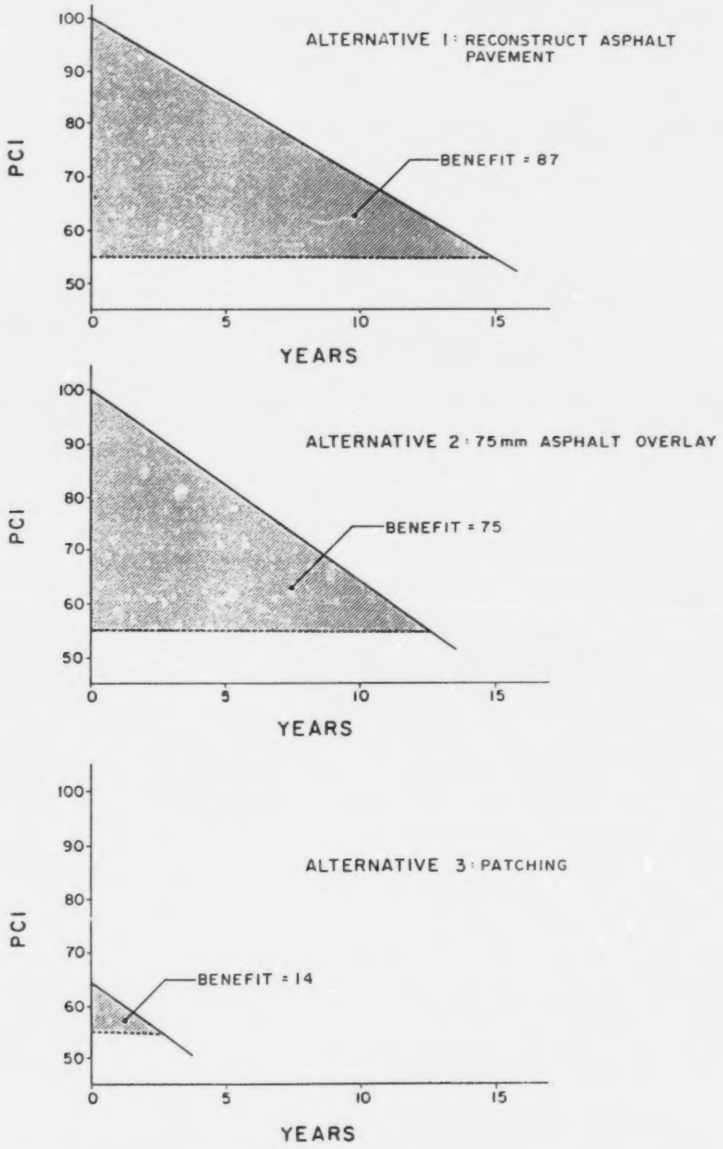


Fig. 7. Example of Benefit Analysis for Centre Drive

formance area, the more reliable the pavement. The benefit program further weights the performance area by utility and relative weight values to give a benefit value.

Utility values are weighting factors representing the relative values of raising the PCI. For example, it would be preferable to raise the PCI on a pavement from 45 to 65 rather than to raise the PCI of another pavement from 80 to 100. Utility values adjust the performance curve to reflect this (Figure 8).

Relative weight values can be applied to compute benefits in order to indicate the importance of each rank of pavement. For example, where two pavements have the same utility-weighted performance, relative weight factors could be applied to reflect the importance of one pavement over the other (eg. arterial vs. residential). For the park roads study, all pavements were given the same relative weight.

The benefits analysis reports the total benefit and the annual benefit of a rehabilitation alternative.

Selecting Optimum Rehabilitation Alternatives for Pavement Sections

The best rehabilitation alternative for a single pavement section can be selected using the information gathered from the life-cycle cost and benefit analyses. (An example is given in Table 2).

In selecting the optimum alternative, the objective is to select the rehabilitation alternative, within budget for the project, with either the maximum benefit-cost ratio; (for example, Alternative 3), or the maximum annual benefit (for example, Alternative 2). (Note that the alternative with the highest benefit-cost ratio does not necessarily also have the highest annual benefit.) Typically, one would select the alternative with the maximum annual benefit for which budget funds are available.

Selecting Rehabilitation Strategies

Developing rehabilitation programs involves determining what work should be done first. Historically, for an urban street system, strategies involved "worst first" prioritization of candidate rehabilitation projects, along with routine maintenance strategies. Using these strategies, and with some adjustment to accommodate traffic and political considerations, a program was established. This approach -- giving attention to streets that look bad -- has a certain logical appeal. This methodology, however, is not consistent with current pavement management research. A number of agencies have determined that rehabilitation costs for maintaining street systems in good condition may be as much as four to five times less than if pavements are allowed to reach poor or failed conditions before rehabilitation takes place.

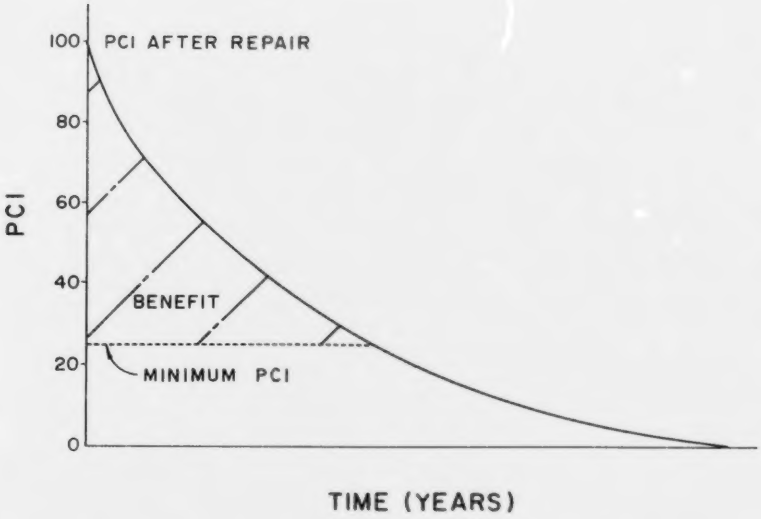


Fig. 8. Benefit (or Performance Area) Adjusted for Utility

TABLE 2

Centre Drive From Conservatory Drive to Cricket Drive
Comparison of Alternatives

Alternative	Initial Cost	Annual Benefit	EUAC/m^2	B-C RATIO
1. Reconstruction	69,600	5.8	5.35	1.08
2. 75 mm Overlay	43,800	6.0	4.50	1.33
3. Patching	13,400	5.0	2.13	2.39

The park roads study "tested" this current research by applying three rehabilitation strategies, namely:

Strategy A. A "repair-when-needed" strategy, where pavement sections had a rehabilitation strategy applied in the year that the section was forecast to reach a particular condition level, as follows:

PCI = 10 or less	Reconstruct to a new asphalt pavement.
PCI = 25 - 30	Overlay (nominal, structural or staged, based on benefit-cost analyses)
PCI = 40 or more	Patching and crack sealing

Pavements in fair or good condition, but with high rates of deterioration received immediate attention, typically in the form of a structural overlay. Restraints were not applied to annual budgets.

Strategy B. Maintain the better pavements. Working with annual budgets between $200,000 and $300,000, priority was given to maintaining the better pavements first using the criteria outlined for Strategy A.

Strategy C. "Worst first" prioritization. With annual budgets typically between $200,000 and $300,000, candidate projects for reconstruction were to receive priority and be undertaken in the year they reached a failed condition. When budget funds became available, asphalt overlays were undertaken.

Comparison of Strategies

With the restrained budget of Strategy B, some candidate projects would have been deferred past the optimum condition levels for rehabilitation. As a result, affected overlay projects were more costly. Failed pavements were to be reconstructed only after all necessary overlays were completed. Reconstruction of four failed sections would have been deferred from 2 to 4 years, resulting in an inconvenience to park users.

Under Strategy C, some candidate projects for overlays would have deteriorated past the identified minimum condition level and would have had to be scheduled for reconstruction. Seventeen sections would be resurfaced under this strategy, versus four sections to be reconstructed under Strategy B. Reconstruction projects, with their associated longer work requirements, are more of an inconvenience to park users than if the same pavement sections were to receive overlays, as in Strategy B.

To determine the impact of each strategy on the condition of the overall road system, the average of the section PCI's was determined for each year to 1990

(Figure 9). This PCI was weighted by section area to account for the different size of each pavement section.The annual budget requirements for each strategy are given in Table 3.

One can determine from this information that, for this case study:

1. the "repair-when-needed" Strategy A provides the highest overall improvement to the park road system with the lowest budget requirement; and
2. with fixed annual budgets between $200,000 and $300,000, the "maintain the better pavements" Strategy B raises the overall condition level of the park road system sooner and at less cost than the "worst first prioritization" Strategy C.

Cognizant of these facts, the City of Winnipeg has budgeted funds to carry out the "repair-when-needed" strategy to restore the park road system. In addition to improving the condition level of the road system at the lowest total cost, the works associated with this strategy could be staged over a shorter time period than the other strategies. The long-term inconvenience to the public was thus reduced.

Had there been a constraint on annual budgets, the strategy of maintaining the better pavements would have been adopted over the "worst first prioritization" strategy, based on its ability to improve the road system more effectively at a lower cost.

CONCLUSIONS

City administrators faced with shrinking budgets require a reliable means by which to make decisions regarding the maintenance and rehabilitation of urban infrastructure -- particularly road systems which have been shown to be in worsening condition. The adoption of sound pavement management principles is one such means.

In the City of Winnipeg, the APWA-COE PAVER pavement management system is being implemented after first being utilized for the Assiniboine Park road study.

The findings of the park road study emphasize the importance of having a methodology for establishing a pavement data base, and procedures from which information can be gathered to determine rehabilitation needs and carry out analyses to optimize priority programming strategies for rehabilitation of road systems. The influence of a constrained budget on optimum strategies also has been demonstrated.

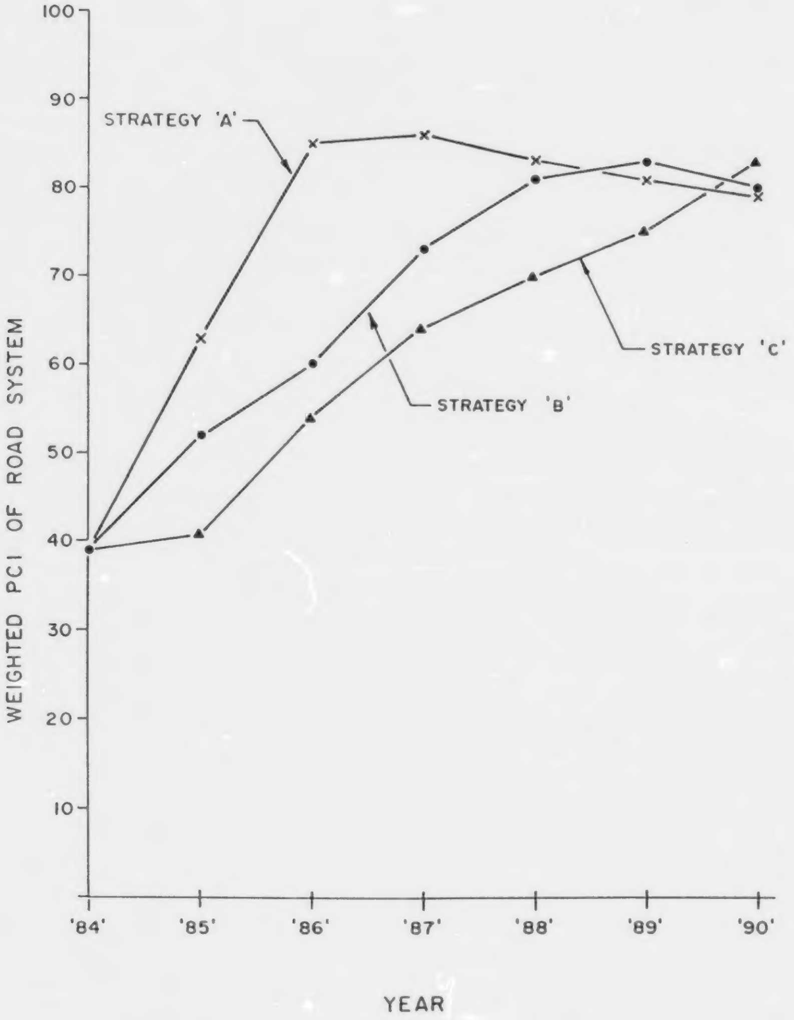


Fig. 9. Weighted Average PCI of Road System for Different Strategies

TABLE 3

Rehabilitation Costs For Various Strategies

Year	Budget Requirement (1985 $)		
	Strategy A	Strategy B	Strategy C
1985	410,000	205,900	200,900
1986	495,300	215,200	334,900
1987	45,300	250,800	263,100
1988	-	233,200	235,800
1989	101,100	143,800	251,400
1990	32,500	26,000	224,500
1991		32,500	28,100
1992			28,100
	$1,084,200	$1,107,400	$1,566,800

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INFRASTRUCTURE NEEDS FOR TRANSIT SYSTEMS

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ABSTRACT

In the current climate of fiscal restraint, roads and transit often must compete for municipal funds. Planners should recognize, however, that in an effective municipal transportation system, the two services are interdependent and should be developed in an integrated and coordinated fashion. Transportation planning that takes the needs of transit into account can lead to substantial savings and socio-economic advantages, as well as help to maximize road capacity. Transit also can be used as a strategic planning tool in controlling traffic patterns and congestion, reducing the need for parking, encouraging land development and maintaining the quality of the environment -- all of which will have long-term effects on infrastructure needs and costs.

When transit is viewed not as an essential component of municipal infrastructure, but as an add-on, capital costs can increase dramatically, and planners relinquish an important strategic tool in their efforts to control urban development. Investment in infrastructure to support transit often realizes more economic benefits to the community than investment in other municipal facilities.

RÉSUMÉ

Étant donné les restrictions financières actuelles, la voierie et le transport en commun se font souvent concurrence pour obtenir des fonds de la municipalité. Les agents de planification devraient toutefois reconnaître que, pour constituer un réseau de transport municipal efficace, le développement de ces deux services interdépendants doit se faire de façon intégrée et coordonnée.

La planification des transport, qui tient compte des desoins du transport en commun, peut apporter des économies et des avantages socio-économiques

considérables, tout en aidant à maximiser la capacité routière. Le transport en commun peut également servir d'instrument de planification stratégique pour contrôler la physionomie de la circulation et les embouteillages, diminuer les besoins de parcs de stationnement, favoriser l'aménagement foncier et préserver la qualité de l'environnement, facteurs qui ont tous des effets à long terme sur les besoins d'infrastructure et le coût de celle-ci.

Les frais d'immobilisation peuvent augmenter radicalement quand on ne considère pas le transort en commun comme un élément essentiel de l'infrastructure urbaine et qu'on le voit seulement comme un ajout. De plus, les agents de planification laissent alors pour compte un instrument stratégique important pour le contrôle du développement urbain. Les sommes consacrées à l'infrastructure afin d'appuyer le transport en commun apportent à la collectivité des avantages économiques qui, en raison de l'exploitation constante de ce service, dépassent souvent ceux des placements faits dans d'autres installations municipales.

COOPERATION BETWEEN ROAD AND TRANSIT PLANNERS NEEDED

I was asked to talk about "urban infrastructure needs for small transit systems." However, what I have to say will be a bit more general because, in fact, both small and large transit systems require the same environment to prosper.

Both require capital and operating funding; both require commitment from the province and municipality; both require some vision to plan effectively for the future; and both require a good working relationship with other urban transportation systems.

I am going to start by talking a bit about transit's relationship with one other element of the urban transportation system: roads.

All too often, transit planners and road planners find themselves on opposite sides of the table, fighting over the transportation share of municipal budgets. Road planners want more and better roads. Transit planners want more and better buses. And there is a limited amount of money to go around.

I am here to assure you that transit supports the need to maintain and renew our roads I am also here to encourage a more integrated and far-sighted approach to planning, building and maintaining urban transportation systems.

Transportation is an extremely powerful force in building cities. From our vantage point in the 1980s, we can look back and see the enormous impact that waterways, then railroads, and then roadways have had on urban development. Our cities do not just happen. They are shaped by planning decisions. The hard part is that the cities of today are shaped by decisions made yesterday.

The Toronto and Montreal of today, for example, were both determined by decisions made during the World War II. At that time, planners decided to develop a balanced transportation system -- one that included roads, transit, and new rapid transit systems.

Construction of the Toronto rapid transit system began in the late 1940s, at a time when most North-American cities were building major roadways only. During the 1950s, with cheap cars, cheap gas and North America's love affair with the automobile, some people questioned the wisdom of that investment in transit infrastructure. But today, many Canadian cities are reaping the benefits of those planning decisions.

A little over 35 years later, we can see the major, positive impact of a balanced transportation system. In a city, such as Toronto, urban transportation systems have shaped land use: industrial development is concentrated along the major roadways while commercial and professional development is concentrated in high-density areas along rapid transit lines. Effective transportation systems -- including roads, transit, rapid transit, rail, ferries and planes -- move people easily and efficiently to and from those centres.

Many Canadian cities have worked hard to combine and integrate transportation modes to provide the best overall mix of speed, capacity, flexibility, and energy use.

Some major urban centres -- such as Los Angeles, Denver, Dallas, and Houston -- did not take such a balanced approach.

And they, too, are reaping the results of their past planning decisions: clogged freeways and cities that have sprawled out over huge, unmanageable areas, which -- many people argue -- have led to social problems and high unemployment.

You may be interested to know that many of those American cities have turned to Canadian transit systems for advice on ways to undo those past decisions. You also may be interested to know that the cost of fixing those problems is many times greater than Canada's original investment in balanced urban transportation.

So the challenge facing all of us here today is to use urban transportation planning as creatively as possible to build the kinds of cities we all want to live in -- not just today, but 10, 20 and -- for our grandchildren and great-grandchildren -- 50 years from now.

We have to be willing to look into the future. We cannot project the needs or solutions of the past into the years ahead. Instead, we should try to anticipate and respond to future demands for urban transportation within what will likely be a very different type of economy.

No matter what the future holds, our urban transportation systems will be more efficient and cost-effective if transit and road planners work together.

GOOD TRANSIT SYSTEM -- GOOD ROADS: AN INTERDEPENDENCE

As I said at the beginning, the transit industry in Canada supports efforts to maintain and renew roadways. Roads are a vital part of the transit infrastructure: the smoother the roads, the better the transit service.

The better the transit service, the more comfortable and efficient the ride and, hence, the more riders will be able to attract onto buses and rapid transit lines.

The better the roads, the longer our vehicles will last and the lower our maintenance and replacement costs.

However, we would like to see included in new and better roads a clear recognition of the needs for a transit infrastructure.

When road renewal is in the planning stages, let us look at the need for and benefits of such infrastructure as bus bays, bus lanes, bus loops, easy pedestrian access to transit, "park and ride" facilities, convenient transfer and terminal points, and so on.

Say, for argument's sake, that in planning major road projects, cities take into account these transit infrastructure needs. There is no doubt that transit service will become more efficient and convenient -- which, in turn, will help transit attract more riders and do its share in keeping the traffic moving.

But what is in it for the roads department and for the city in general?

First and foremost, there will be less congestion on the roads which should make the job of the roads department easier. In addition, in many cities, road planners help justify the need for road repairs by including the benefit to transit. Some municipalities use transit service as an evaluation factor in setting priorities for road repairs.

Determining transit infrastructure needs before renewal projects are underway will also save money. Including a bus bay when a road is being completely redone is relatively inexpensive. Adding a bus bay 5 years later, when traffic levels have increased and transit vehicles are interfering with smooth traffic flow, is very expensive.

Infrastructure that helps transit move efficiently -- such as bus lanes, transit signals and regulations -- will help all traffic move efficiently. Some infrastructure elements, such as bus bays, actually benefit traffic managers more than transit operators. Bus drivers would prefer to stop in the streets and avoid the problem of pulling back out into traffic. However, we use bus bays to get stopped transit vehicles out of the way and keep traffic moving. In return, we would like traffic planners to help us develop effective ways of getting the buses out of the bus bays and back into the stream of traffic.

Transit also helps road planners by easing the pressure on road systems. Our figures show that approximately 25% of all urban trips in Canada are provided by transit. In Toronto, during peak periods, 80% of passenger trips to and from the city centre are provided by transit. If just half of those people stepped out of transit vehicles and into their cars, Toronto would grind to a halt. The road system could not handle the volume.

Even a 10% increase in the number of cars on the road would have a negative impact on roads and traffic patterns in most Canadian cities.

Transit can also help city transportation planners maximize road capacity.

Somewhere between 25 and 80% fewer cars on the streets also means less pollution, fewer accidents and traffic mishaps, and less need to tie up valuable city property to provide parking lots.

Those are the benefits that transit offers to road and traffic planners. But transit also contributes in other ways to our communities.

GOOD TRANSIT: A SOCIO-ECONOMIC FORCE

For example, transit is a social service: a means of transportation for students, older people and those who cannot afford a car. Transit also has a positive impact on traffic patterns, land development and property values.

Recent studies indicate that transit is an important factor in retail sales and employment.

OC Transpo in Ottawa and the Ottawa-Carleton Board of Trade published the results of a passenger survey in October 1986. Of the riders interviewed, 80% said that bus service was important for getting to work, 72% said it was an important factor in determining where they live, and 66% said it was important for shopping. According to the survey, OC Transpo riders who cite shopping as either the primary or secondary reason for their trip spend well over $500 million each year in Ottawa stores. About 70% of that is spent in downtown Ottawa, the remaining 30% is shared among regional shopping centres and other locations.

If I were a retailer trying to choose a location for my store in Ottawa, or a planner trying to shape urban development, I would find that interesting and useful information.

A report completed in March 1985 by the University of Cincinnati looked at the economic impact of Queen City Metro, which provides about 20 million adult trips each year, on Greater Cincinnati. Roughly half those trips are work-related. Some type of shopping is done as part of 26% of the trips. The average passenger spends between $13.00 and $23.50 in the course of each trip; overall, passengers spend an estimated $200 million annually. The study also discovered that the transit system makes it possible for about 3,100 people, who do not have -- and could not afford -- other means of transportation, to be employed. Researchers projected that, if the bus were not available, close to 1.9 million trips currently taken would not be made. Alternative modes of transportation would cost an extra $6 million, and more funding would be required to maintain the transportation system.

In 1984, the American Public Transit Association looked at the national impacts of transit capital and operating expenditures on business revenues using a model provided by the U.S. Department of Commerce. The Association determined that $100 million spent on buying buses generates some $350 million in business revenues. A clear three-to-one ratio.

Within the transit industry, we also have figures on job creation. In 1983, the American Public Transit Association published data which showed that $100 million spent on buying buses created 3,149 direct and 4,301 indirect jobs. One hundred million dollars spent on running transit created a total of 4,063 direct and 5,550 indirect jobs. Transit is an extremely labour-intensive operation -- even at the manufacturing level -- and that is not likely to change substantially over the next 30 years. Transit suppliers simply do not have the volume to justify a major investment in robotics or automation.

Investment in transit infrastructure also offers Canada another potential benefit: the opportunity to develop a strong export market for our transit products. We in Canada are among the world leaders in transit. There is a great opportunity to market our rolling stock, technology and experience abroad -- an opportunity we will lose if we do not continue to invest in transit.

In summary, transit:

- provides a social service for older people, students and those who are socially disadvantaged;
- helps control traffic congestion -- helps increase road capacity and keep cities moving;
- reduces pollution and uses less energy;
- reduces the need for downtown parking;
- helps shape traffic patterns;
- encourages land development;
- increases property values;
- generates retail sales;
- creates business revenues;
- creates jobs and helps people stay employed;
- encourages research and development in a field where Canada is a recognized leader; and
- contributes to our balance of trade and our GNP.

For all these reasons, transit is a powerful social and economic strategic planning tool.

COOPERATION AMONG PLANNERS IS HAPPENING

Urban transportation planners have a choice. They can make minimal use of transit, providing service only for those captive riders who have no alternative but to use transit. Or they can make the transit service in our cities as cost-effective as possible, reap all the benefits that transit offers, and create cities that will move effectively 10, 20, and 50 years from now.

In our view, the transportation industry probably will see at least as many changes in the next 20 years as it has in the last 20. Our economy depends more and more on a multi-modal transportation system, therefore, urban transportation planners have to develop effective links between all elements of the system.

Those of us working in transit ask that urban planners keep in mind the needs of transit. Transit is a service. To succeed, to be cost-effective, to provide all the benefits we can offer, we have to provide comfortable, convenient service. We have to get our riders as close as possible to the offices, stores, airports, train stations, restaurants, cultural centres, ballparks and homes they travel to and from. We have to provide service they can depend on with the fewest possible delays and the least possible noise or hassle. Urban planners can help us do that.

Urban planners also can help us by being aware of the potential future demands for transit. Make the kind of decisions now that will protect our options in the future. Land bought or held now in anticipation of rapid transit projects or busways 10 or 15 years hence will help keep our options open. Land sold for short-term gain may have serious long-term consequences for urban transportation.

In turn, we can help planners maximize road capacity, alter or adjust traffic patterns, and determine high- and low-density development areas. In the future, we must face the fact that we cannot respond to growing needs by endlessly widening our roads. There are other solutions; the strategic use of transit is one of them. The co-operation I am encouraging between road and transit planners has already begun and, I am happy to report, is working well. In some smaller cities in Canada, the road planner is also the transit planner. Our cities are beginning to reflect a truly integrated approach to urban transportation which, if we stay attuned to economic changes that are taking place in the world around us, will help us plan now for the future.

NEEDS OF TRANSIT SYSTEM MUST BE HEEDED

To provide social and economic benefits, transit infrastructure must be maintained and improved.

We need maintenance facilities and the ability to replace aging rolling stock before equipment failures cause us to lose riders.

We also need an environment that encourages transit. As an industry we are still fighting the assumption that we should pay our own way. We always hear that transit operates at a deficit. We never hear that roads or libraries or schools or other municipal services operate at a deficit.

That was not always the case. For example, before the advent of railroads, Britain had a well-developed nation-wide network of toll roads. With the railroads, enough traffic was diverted that some people suggested that the road network be abandoned. Ultimately, it was decided that there was, after all, some social value in keeping roads. They provided an alternative in case of problems with the railroad system and, in any event, there was certain traffic captive to the roads. So it was arranged that roads were passed from private enterprise operations to the public sector where they operated at a loss. Taxpayers were extremely unhappy and it took some years to sort things out.

Although hardly anyone ever speaks of road deficits, Canadian transit deficits have closely tracked those of Canadian roads. The cost/revenue ratio of Canadian roads fell from 67% in 1969 to 39% in 1979. Cost recovery for transit fell from 72% in 1974 to 53% in 1981. Which proves that both forms of transportation are subject to the same kinds of economic and market pressures.

In developing urban transportation systems, there will always be trade-offs. The process is one of comparing alternatives to determine the most cost-effective and efficient solution. We will always be comparing the cost of a transit solution to a road solution to a rail solution and so on. And that's how it should be. But if we are going to talk about comparisons and assessments, let us find a common basis for comparing infrastructure alternatives.

If we are going to look at deficits, let us examine all the related deficits. If we are going to look at cost recovery, let us expand our thinking beyond the transit fare box and the vehicle license fee to include the other, less quantifiable but very real economic benefits of transportation systems.

Let us make our infrastructure investment decisions using -- as far as possible -- common cost/benefit and subsidy criteria across all modes. In this way, we are more likely to develop the most appropriate transportation mix.

VENI, VIDI, VICI

On behalf of the Canadian transit industry, I would like to tell you that we look forward to working closely with road planners, inter-city rail, bus systems, and other transportation modes to shape the cities of the future.

In conversations about transportation planning, a colleague of mine often refers to the pedestrian viaducts the Romans built to move their legionnaires. They could hardly have anticipated that today those same viaducts would carry automobiles. If those Roman planners could see the results of their work, they would be somewhat startled -- and probably pleased.

While neither our roads nor our transit vehicles have the life-span of a Roman viaduct, we should work together to make the kind of decisions today that will have a welcome place in the urban transportation systems of tomorrow.

BUILDING CONDITION ASSESSMENT

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ABSTRACT

The consequences of the low level of building construction activity during the depression and war years on the quality of construction during the post-war boom years are discussed first. Departure from traditional building designs, and the emphasis on low capital cost, set the stage for some fairly major problems which, along with the effects of aging, have led to increasing levels of renovation and replacement.

The lack of as-built documentation, advanced non-destructive evaluation tools, economic and risk models and remedial action will be considered. Detailed examples of existing methods and tools for building diagnostics will be provided, as will a series of recommendations on the following subjects:

- establishment of a central building diagnostics data bank;
- development of models for selecting buildings and critical components in need of detailed evaluation;
- development of economic models for renovate/replace decision-making;
- development of life-cycle safety-related models;
- the design and documentation of new buildings with their ultimate repair and replacement in mind;
- development of specific instruments for building diagnostic purposes.

RÉSUMÉ

M. Timusk discute d'abord des effets du peu d'activité du secteur du bâtiment pendant la dépression et la guerre sur la qualité de la construction durant les années d'expansion économique de l'après-guerre. L'abandon des modèles traditionnels et l'importance accordée à la réduction maximale des immobilisations ont amené certains problèmes assez graves qui, conjugués au vieillissement des bâtiments, ont obligé à entreprendre de plus en plus de travaux de rénovation et de remplacement.

M. Timusk examine ensuite le manque de documentation sur les bâtiments construits et discute d'instruments perfectionnés d'évaluation ne supposant aucune destruction, de modèles économiques et d'évaluation des risques et de mesures possibles pour remédier aux problemes constatés. Il donne des exemples détaillés des méthodes et instruments diagnostiques existants et fait une série de recommandations sur les sujets suivants:

- établissement d'une banque centrale de données diagnostiques sur les bâtiments;
- mise au point de modèles de sélection des bâtiments et des éléments critiques nécessitant une évaluation détaillée;
- élaboration de modèles économiques permettant de décider entre rénovation et remplacement;
- établissement de modèles axés sur la protection de la vie;
- conception de nouveaux bâtiments en tenant compte des travaux de réparation et de remplacement éventuels, et préparation de documents pertinents;
- mise au point d'instruments précis aux fins du diagnostic de l'état des bâtiments.

INTRODUCTION

The useful life of a building is finite. Eventually the point is reached where expenditure exceeds income and where economic considerations dictate that the building be replaced; investment in repairs and renovation cannot be recovered over the remaining life of the building. Allowance has to be made for intangibles such as safety and historical considerations. These may be difficult to evaluate in monetary terms, but they nevertheless have economic overtones such as increased insurance premiums.

The service life of some building components may only be a few years before they need to be replaced, usually at reasonable cost and minimum inconvenience to the building users. Others are such that replacement is out of the question; when their service life is used up, so is that of the building.

In some cases the service life can be predicted with reasonable accuracy. This is usually the case when the component has been previously in use for more than one service life (information about component performance travels extremely slowly in the building industry) and where the service environment does not vary significantly from application to application. In most instances, however, the materials, details and designs were developed during the course of the building of the present infrastructure, and no in-service information over the service life is available. Matters are further complicated by the difficulty of predicting the service environment, which in the case of the building thermal envelope, is not only determined by local climate (wind, rain, temperature, solar radiation and atmospheric pollutants), but the very design in question which creates its own internal climate.

The current condition as well as the remaining service lives of vital building components must nevertheless be determined.

BACKGROUND

The depression and war years saw very little construction activity. At the end of hostilities, an unprecedented demand for new construction was created by increased urbanization, a large influx of immigrants, and simply by the need to catch up with demand that was not satisfied during the depression and the war years.

An examination of the mean annual size of the labour force employed by contractors and trades provides an indication of the rate of growth: from 1935 to 1945 it was reasonably constant, but grew from about 71,000 in 1945 to some 407,000 by 1957, a 470% growth in 12 years!

Even if building practice had remained unchanged, the training of 330,000 new workers over such a short time would have been a formidable task. Theoretically, one master should be able to look after up to five journeymen to provide on-the-job training. Experience from the examination of building failures suggests, however, that the quality of workmanship was not always up to the required standards.

The building industry, in particular, depends on a well-qualified work force which to a large extent provides its own quality control and inspection. Work is usually carried out over an extensive site and becomes quickly covered up by subsequent construction, making third-party supervision difficult at best. The difficulty of training workers and supervising work on the job site has been cited as one of the reasons for favouring factory-built buildings for the reconstruction of Europe after the war.

It would be grossly unfair even to suggest that construction workers alone were responsible for the at-times questionable quality of the urban building stock. The issue is far more complex. A second reason has to be attributed to the building professionals who were overwhelmed by the rate of change of building practice.

If the reliance on science was the hallmark of the industrial revolution, then the building industry has yet to enter the industrial age. Things worked very well for the construction industry as long as the change was evolutionary. Change by trial and error was wasteful but with localized experimentation, the consequences of illfated experiments were not serious. The master builder who later became the architect could safely operate in such an environment without significant scientific training. No prediction of the performance of a new building was necessary (a process which would require the use of science) because the new building was essentially a copy of something that had been built before, over and over again.

With minor exceptions our universities have failed to train professionals for the construction industry and support research on its behalf. It should not be surprising, therefore, that many of our buildings have become experiments at the expense of the owner. This applies equally well to engineering as to architecture.

Rigid jurisdictional boundaries have contributed their share to the problems. The separation of responsibilities between architects and engineers within the same structural element has more or less guaranteed incompatibility. Individually the two sets of drawings, the architectural and the structural drawings, are fine as long as one set applies to buildings without engineering and the other to buildings without architecture.

It is when the two are combined in one building that we can run into difficulties. Sometimes the thermal insulation is placed on the wrong side of the structural wall so that restrained thermal movement tears the wall apart, or the structural framework makes it impossible to install the seals to make the construction airtight. The lack of compatibility between the two professions has been left to the trades to resolve on the job. The result is neither what the designers intended nor what shows on the plans.

The emergence of new materials and building products has had a mixed effect on the quality of buildings. On the positive side, much pressure has been removed from the building trades by technical innovation provided by the building products industry, such as pre-blended masonry cements, gypsum dry wall and plastic plumbing to mention but a few. At the same time, the rate of introduction of new products without research industry backing to develop performance evaluation processes, without predicting adverse interactions, or without developing effective technology transfer to the parties concerned is regrettable.

Finally, speculative building, misguided economizing and inadequate maintenance have to be added to complete the picture.

Our infrastructure, which by and large came into being over a relatively short time, soon will reach the age when major repair, renovation, and remedial action will be called for. If the industry does not prepare itself to meet this new bulge, it will be overwhelmed by it.

That timely remedial action is preferred to reaction after failure is clear. That tools presently are not available to predict the condition of a building without a physical inspection of the building is also clear. Nor can it readily be established when a building should be inspected, what should be examined and what analysis should be carried out.

THE INSPECTION PROCESS

No simple answer can be provided to the question about frequency of inspection and the extent of it. Nor is there a clearcut answer to whether one should wait for the failure to occur or anticipate it and take appropriate prophylactic action. The inspector must be able to foresee the consequences of errors that could result from the process. Yet another category of failure is one where the visible failure is only a symptom of a more serious concealed problem. The following is provided as an illustration of this.

Even before this building was completed, rain water was leaking through some of the exterior walls. At first relatively minor damage was done to the interior finishes. All attention was focused on the exterior wall surface cover which had become detached from the walls in some locations. When a more detailed examination was conducted several years later, it was found that sufficient hidden damage to the structure had occurred to require replacement of the walls. To rectify the problem when it was first detected would have cost an order of magnitude less than the replacement of the wall. The wall had failed because of a basic design error which, among other things, resulted in the outer finish becoming detached. Had a building science specialist been engaged in the first place, it is most likely that a correct diagnosis and appropriate remedial action would have been provided in the first place.

Frequency of Inspection

Continual inspection is part of curing for any building in use by those whose task it is to maintain the building, by specialists with routine contracts to service elevators, heating ventilating and air-conditioning plant, and by the building users themselves. The amount of useful information obtained from such routine maintenance can be enhanced by instructing those involved in the process to look out for specific indicators that warrant more detailed investigation. Even window washers could be instructed to report visible facade deterioration. From a swing stage they have a close view of otherwise inaccessible parts of the envelope. For a small extra cost valuable information could be procured.

The discovery of problems is only useful, however, if they are reported and appropriate action is taken. Along with instructions on what to look for must go instructions on how and to whom to report.

Along with casual inspections, detailed expert inspections must be conducted. They are naturally costlier and their frequency and extent should therefore be optimized. In the following sections the question of frequency and kind of inspection are discussed and illustrative examples addressing the building thermal envelope are given. Similar concepts can be applied, no doubt, to other building systems.

A rough parallel can be drawn between the amount of health care required by people and that needed by buildings: during the early years basic deficiencies surface; they are followed by relatively trouble-free middle years, then comes the geriatric period with its many health problems.

Inspection During the Early Years

A proper building commissioning process should reveal a significant number of the possible deficiencies. In the case of the building thermal envelope, at least one year is needed to bring out major design, detailing and construction defects. Some such defects are:

1. Thermal movement. Either restrained thermal strain leading to stresses sufficient to cause cracking, or excessive differential thermal movement resulting in the opening of joints may occur during temperature extremes, cyclic temperature because of variation or in combination with moisture-induced strains. The consequences may range from minor water penetration and air leakage to actual collapse.

2. Time-dependent deformations. These include the effects of creep and shrinkage on building components, such as those made of reinforced concrete or timber. For example, as most of creep and shrinkage of concrete will have occurred during the first 2 or 3 years of the life of the structure, construction where no allowance has been made for frame shortening and where load is inadvertently transferred to clay brick veneer would fail in the early years of the building.

3. Freeze-thaw damage. Freeze-thaw damage of clay masonry, for example, requires the combination of a clay brick with frost-susceptible structure, critical moisture conditions, below-freezing temperatures and a number of freeze-thaw cycles. The combination of non-durable brick and wet service conditions result in failure in a relatively short period of time. Most locations in Canada have at least 50 freeze-thaw cycles per year. One of the essential ingredients for freeze-thaw damage is an excessive amount of water, leading to critical saturation of the masonry. The failure of the clay masonry is itself but a symptom of water getting into the construction. It then must be determined how water got into the construction, and steps taken to remedy the situation, so that concealed deterioration does not lead to corrosion of essential fasteners and then to failure without warning.

Inspection During the Middle Years

Once the deficiencies have surfaced and been corrected, the building should provide a relatively long period of trouble-free service. Routine inspection of elements with short service lives, such as seals, roof membranes, and flashings is essential, however, to prevent entry of water into the thermal envelope where serious structural damage can result. Relatively major replacements of defective components, such as roof membranes and mechanical systems, may be required during this period.

Inspection During the Advanced Years

The life of the building components is finite. The materials of which they are made naturally seek a more stable state: metals are converted to their oxides, wood to carbon dioxide and water, and masonry to sand and clay-sized particles. It is really not a case of the materials failing, but rather of the materials having been placed in an environment for which they are unsuitable.

Metals. Metals corrode at a rate dependent on the local environment which, in turn, is determined by the local micro-climate and the building detailing itself. Lately, the level of atmospheric pollution has increased to the extent that corrosion rates have become unprecedented. The water supply of each municipality has unique corrosive agents which affect the service life of hot-water systems. The use of corrosion-resistant materials does not necessarily guarantee control of corrosion: water containing dissolved salts or acid and, especially at elevated temperature, can increase the reaction rates by more than an order of magnitude. With not knowing the service environment, making reliable long-term predictions about the service life of building components is particularly difficult.

Masonry and concrete. The rate of diffusion of water and gases through masonry materials can be very slow. Nevertheless, over decades, sufficient internal damage through solution of original materials, reaction with ions diffused into the structure, and deposition of salts in the pores eventually can result in the failure of materials. Familiar examples of this are the corrosion of reinforcing steel when the natural protection provided by the hydration products of portland cement is lost due to carbonation and the diffusion of chloride ions and oxygen into the protective layer. Similarly, after many decades and even a century of service, clay masonry, portland cement concrete, or sandstone masonry start to disintegrate because of salt crystal growth in the pores. Structures, weakened by leaching, also become more susceptible to freeze-thaw damage.

The consequences of corrosion and decay of materials in buildings becomes particularly serious when it takes place without obvious superficial signs and suddenly results in a catastrophic failure endangering property and life.

Expert Inspection

It cannot be stressed strongly enough how important it is that a building science specialist be engaged during all phases of an investigation. Experience in the geographical area and with the type of structure is advantageous. Usually the inspection process comprises three stages:

1. planning and preliminary investigation;
2. execution of field work; and
3. analysis and reporting.

Planning and preliminary investigation. A large part of this work, such as examining plans and drawings and relevant reports, can be carried out in the office. Usually one or more visits to the building are required to interview the building maintenance staff and to tour the building with them to examine areas where visible signs of problems have surfaced.

Some probing into the envelope where relatively easy access is possible may be done at this stage. This would include looking into plenums, removing wall-covering panels, when practical, to establish as well as possible the as-built and current conditions of the building. Probing of the outer face of the walls from a swing stage also may be required during the preliminary field survey.

Where to probe is determined from a careful analysis of all available information for the building in question, previous experience with similar buildings, and a theoretical analysis of the building.

Based on the preliminary investigation, a proposal is developed for the detailed inspection and, if appropriate, presented for approval to the building owner.

Execution of Field Work. Because inspection and repair are rarely taken into consideration during the design of a building, access to vital envelope-forming components is seldom possible without removing envelope components. From the outside this usually means cutting masonry out at key locations. When required, the cut masonry can be taken to the laboratory for detailed examination. Because of the relatively high cost of such cuts, it is important to make them at the most likely-to-fail locations.

It is not unusual, however, to encounter cases where vital components are inaccessible. Then what approaches partial demolition of the building may have to be undertaken. Non-destructive methods, such as the use of fibre optics, need to be developed for such cases.

Where to cut may be suggested by surface indicators: material failure, efflorescence, mould and mildew on inside surfaces. No reliable tools exist for non-destructive examination of the concealed parts of construction. Tools, such as infrared thermography, can assist in the diagnostics. This technique provides only the surface temperature distribution, but when it is compared to calculated values, anomalous behaviour may be detected. What causes it may still remain to be determined by other means; it could be due to missing, incorrectly positioned, or wet insulation, by air leakage through the wall, or by an unanticipated thermal bridge introduced during construction but not documented.

Water can get into the insulation from rain penetration or from the inside when moisture condenses from exfiltrating air. Air pressure measurements across the envelope, correlated with wind, stack and fan-induced pressures will provide additional information. Further insight can be gained by reversing the pressure across the wall under investigation by means of a door-fan and observing the change in temperature patterns.

Each time a wall is examined, a more or less unique set of circumstances prevails. The circumstances are determined not only by the temperature across the wall and wind conditions at the time of measurement, but also by earlier conditions, such as the temperature and solar radiation of the previous day and the accumulation or loss of moisture during the previous couple of weeks to months. For example, moisture conditions in a wall in late October, after summer-drying, will be markedly different from those in late March, when exfiltration-transported moisture is at a maximum.

If these various methods still do not establish the cause for the anomaly, the wall may have to be opened for direct visual examination. Where very large areas with potential moisture problems, such as flat roofs, are to be investigated, infrared monitoring may be augmented or even replaced by techniques where neutron back-scatter is measured to establish water content.

Many other tools and techniques are available for thermal envelope investigation. Often it is not immediately evident from a single observation what the extent and cause of a problem is. In such cases the field observations have to be interpreted by a skilled building scientist.

Analysis and Reporting. Because this work is carried out in the office, carefully taken field notes and a comprehensive photographic record of the field work are invaluable. Even then it is not unusual to have to return to the building to obtain more information. This is a characteristic of building assessment; in complex or unusual cases where conclusions have to be drawn from circumstantial evidence, the need for additional information may first be realized during the course of analysis.

Many of the steps and procedures described may not be needed for an assessment. In the case of an inherently safe building, a single field tour may verify that the building is unlikely to require immediate remedial action. Whatever the case, the building owner should be provided with a clear report indicating whether action needs to be taken, if not immediately then at what future date. At the same time, it should be stressed that the conclusions reached may be based on rather indirect evidence and, if possible, the reliability of the conclusions should be indicated.

FUTURE CONSIDERATIONS

The extent and severity of corrosion of parking structure reinforcement has been known for more than a decade. In spite of all the efforts made by the concrete industry, which itself is served by a long-standing tradition for research and development, no feasible solutions to this problem have been found.

When our present building stock reaches the age when major envelope problems emerge, solutions will be even more difficult to generate for several reasons. The number of combinations of building materials and their exposure conditions is very large and often peculiar to a geographical location and local building practice. The tradition of research in this field, with a few exceptions, is very poor. Universities largely have neglected to educate the professionals required by this field or to support it with research.

Because it will take a considerable amount of time to generate the capacity to deal effectively with the oncoming bulge of building repair, rehabilitation and renewal, steps to prepare for it should be taken now. Some of the requirements of the building industry to meet this demand are:

- education of building professionals by universities;
- development of expert systems;
- establishment of a database; and
- research and development.

Education of Building Professionals by Universities

In addition to introducing building industry-related courses into the undergraduate and graduate programs in the faculties of architecture and engineering, specialized education and training of building professionals who already have demonstrated interest and have experience in the industry is needed. Various vehicles could be used for such training, ranging from extension and diploma programs to graduate degree programs. The full potential of this approach cannot yet be reached, regardless of the level of funding provided, because specialists to deliver such programs first must be developed. Unfortunately, it is unlikely that universities will initiate such new programs under the current conditions of fiscal constraint. To do this would require that funds be diverted from other programs which themselves are already underfunded.

Development of Expert Systems

Suitable expert systems could be developed to improve the quality of building assessments while at the same time reducing the education and training requirements for building professionals charged with this work. Similarly, for building managers, expert systems related to building maintenance, repair, and assessment could also be produced.

Establishment of a Database

It has taken too long not only to fully appreciate the extent and gravity of parking structure corrosion, but also to transfer this knowledge with the available solutions to those concerned. Better coordination of data acquisition, analysis, solution development, and technology transfer could have avoided much of the damage that has occurred. The same mistakes need not be repeated for all the other building-related problems. A systematic documentation of relevant case histories, their analysis, solution development and transfer to concerned organizations seems appropriate. To avoid unnecessary duplication, this should be coordinated and perhaps even executed by a single central organization, such as the Institute for Research in Construction of NRC.

Research, Development, Demonstration and Implementation

Somehow a case must be made to the concerned parties to support RDD & I in this field. While its cost may seem high when viewed in terms of traditional building industry research expenditures, the cost of not doing it will be staggering.

AN AIR BARRIER FOR THE BUILDING ENVELOPE

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ABSTRACT

A misunderstanding of the principles of enclosure design has caused rapid deterioration of many building facades. How structural materials can be affected adversely by a decision-making process based on tradition and popular belief rather than on building science is illustrated.

RÉSUMÉ

Une mauvaise compréhension des principes de conception est la cause de la détérioration rapide de nombreuses façades de bâtiment. Comment les matériaux structurels peuvent subir les effets de décisions fondées sur la tradition et les croyances populaires plutôt que sur la science du bâtiment

WHAT IS CAUSING ALL THE CONFUSION?

During the past few years the architectural industry has been burdened with confusion surrounding the air and vapour barrier requirements for the building envelope. This confusion has been reflected in architectural drawings, identified by such phrases as: air/vapour barriers, vapour retarders, wind barriers, and air barrier preservatives. Manufacturers of construction products have responded with the introduction of air barrier materials with names such as: Sopraseal, Perm-A-Barrier, TFM, BlueSkin, AirBloc, PermSeal, ElastoSeal, PressureSeal and Air Preservative.

Further confusion has been created with the implementation of Section 5.3 of the building code, stating that an air barrier is required for the building envelope. However, no standard or minimum acceptable requirements are stated, leaving the industry in turmoil.

The concept that must be reiterated is as follows: an air barrier is not a material, rather it is part of building envelope design.

A successful building science approach to the air barrier concept requires assembling a team to design, specify, and control construction to the completion of the building. The owner, architect, manufacturer, and builder must all play a role to produce the desired effect. Their involvement, however, will add to the cost of construction.

Performance specification is now looked upon as a simple way of ensuring a quality product. But it does not relieve the architect from his responsibility to ensure that the requirements will be met.

INDOOR AIR QUALITY (IAQ): ISSUES AND OPPORTUNITIES

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ABSTRACT

While the emergence of indoor air quality (IAQ) as a major health issue has coincided with the introduction of certain energy conservation measures in buildings beginning in the mid-1970s, IAQ implications extend far beyond this. For example, consideration of IAQ implications is beginning to have a new or increased influence on the design and selection of building materials and furnishings; on the design, selection, maintenance, and operation of building heating, cooling, humidification, and air handling systems; on the design and operation of cooking systems; and on the acceptability of openable windows and tight-enclosure buildings.

RÉSUMÉ

La qualité de l'air à l'intérieur des édifices est devenue une préoccupation majeure vers le milieu des années '70, en méme temps qu'apparaissaient certaines mesures destinées à assurer la conservation d'énergie. La qualité de l'air à l'intérieur dépasse cependant cet aspect. Ainsi, la qualité de l'air à l'intérieur des édifices commence à exercer une influence ou à augmenter son influence sur la conception et la sélection des matériaux de construction et des équipements, sur la conception, le choix, l'entretien et l'exploitation des systèmes de chauffage, de climatisation, d'humidification et de traitement de l'air, sur la conception et le fonctionnement des cuisines, sur la possibilité de permettre l'ouverture des fenêtres et enfin sur les enceintes totalement fermées.

As health authorities, building managers and scientists continue to discover new chemical and biological pollutants indoors, often at levels exceeding those outdoors, there seem to be good reasons for concern. This is particularly true for many Canadians and peoples of other cold climate regions who spend most of their time indoors during winter months, both in their own residences and in schools, offices, ice arenas, and other facilities.

An extensive program has been underway in Canada for several years to identify and alleviate the health impacts of urea formaldehyde foam insulation (UFFI) which had been used in many, often older residences, and was banned in 1980. Other major programs are being carried out to assess and control residential radon exposures and to develop mechanical ventilation techniques for tight-enclosure houses.

In the United States and Europe, broad studies are focussing on identifying pollutants associated with "sick" buildings. They are also assessing the levels and impacts of unvented combustion pollutants, of involuntary or passive tobacco smoke inhalation, of formaldehyde exposures, particularly from pressed wood products in mobile houses, of exposure to radon in homes, and of biological pollutants, such as legionella bacteria, associated with pools of stagnant water in HVAC equipment and continuously wetted building materials.

INDOOR POLLUTANTS AND THEIR CONTROL

Pollutant Standards

While the U.S. Environmental Protection Agency (EPA) has set national ambient air quality standards (Table 1) (EPA), parallel standards for indoor air have not yet been promulgated. However, the World Health Organization (WHO) Working Group on IAQ has developed some guidelines, also shown in Table 1.

The U.S. National Council on Radiation Protection and Measurements (NCRP) has recently recommended an indoor radon standard of 2 WLM/year which is equivalent to an indoor concentration of 8 pCi/L.

The U.S. Housing and Urban Development Agency (HUD) has set a target formaldehyde level of 480 ug/m3 (0.4 ppm) for mobile homes. It is expected that this target will not be exceeded if product emission standards for particle board and plywood, as measured in large chamber tests, are set at 0.32 ppm and 0.2 ppm, respectively, if the indoor temperature does not rise above 25^0C, if the relative humidity is less than 50%, if the ventilation rate is at least 0.5 air changes per hour, and if there are no other major emitters of formaldehyde.

The U.S. National Institute on Occupational Safety and Health (NIOSH) has been investigating airborne particles of biological origin such as bacteria, moulds and fungi, and developing guideline levels based on the numbers of colony-forming units (CFU) present in the air. One number suggested is 1000 CFU/m^3.

Table 1

Some Air Quality Contaminant Concentration Criteria

Contaminant	EPA Ambient Air Standards			WHO Indoor Air Guidelines			
	Time	Level		Concentration of Limited or no concern		Concentration of Concern	
		$\mu g/cm^3$	ppm	$\mu g/cm^3$	ppm	$\mu g/cm^3$	ppm
Carbon monoxide	1 h	40 000	35				
	8 h	10 000	9	11,1000	9.6	30,000	26
Carbon dioxide				4.5	2500	12	6700
Lead	3 mo	1.5					
Nitrogen dioxide	1 yr	100	0.055	190	0.1	320	0.17
Ozone	1 h	235	0.12	120	0.06	150	0.08
Sulphur dioxide	24 h	365	0.14	500	0.2	1350	0.5
	1 yr	80	0.03				
Formaldehyde				60	0.5	120	0.1
Particulates	24 h	260					
	1 yr	75					
Asbestos					0	0.1 fibre/cm^3	
Radon					0	70 Bq/m^3 (2 pCi/L)	

Finally, the level of ambient carbon dioxide due to human respiration is generally considered to be a reasonable indication of the ventilation rate and the overall level of indoor air pollutants. In Japan, indoor carbon dioxide levels are to be less than 1.8 g/m^3 (0.1 percent or 1000 ppm). Where air-cleaning devices are employed or where there are non-human sources of CO_2, this value may not be appropriate.

Mechanisms for controlling these and other indoor pollutants include increasing indoor-outdoor air exchange rates where the outdoor air has lower concentrations as is normally the case; improving internal air circulation; cleaning the air to remove particles and gases; and eliminating or reducing pollutants at source. Normally, control at source is the most effective mechanism, although particular circumstances may govern the most cost-effective approach. Since many indoor pollutants cannot be eliminated at source or by air cleaning, at least some outdoor air will be required.

VENTILATION STANDARDS

Since 1973, ASHRAE has maintained a building ventilation standard that is generally applied in North-American buildings. Standard 62-73 specifies minimum and recommended ventilation rates, with the recommended rates generally exceeding the minimum rates by factors of 1.5 to 12.

However, ASHRAE Standard 90, which is concerned with energy conservation in new buildings, recommended adherence to the minimum ventilation values specified in Standard 62-73, when it was first issued in 1975 and again in 1980. With the increased IAQ concerns, a new version of the ventilation standard eliminating this 'minimum and recommended value' approach was issued.

ASHRAE Standard 62-81 specifies two minimum ventilation rates in non-residential buildings, one for settings with tobacco smoking and a much lower rate for settings with no smoking. In this standard, a portion of the ventilation air can be recirculated, provided it is treated to meet the ambient air quality standards. In addition, Standard 62-81 specifies an alternative air quality procedure in which lower ventilation rates can be used, provided specified pollutant concentrations are not exceeded and odor levels are acceptable to 80% of a 20-person panel of untrained observers.

Until Standard 62-81, the ASHRAE ventilation standard had been applied only to mechanically ventilated buildings, which essentially excluded single-family residences because these rely on infiltration and natural ventilation (windows and vents). During the review period, ASHRAE 62-81 was challenged by the Formaldehyde Institute because of the 0.1 ppm standard for formaldehyde. The Institute felt that inclusion of this new formaldehyde criterion in the Standard would cause problems for residences, especially for manufactured housing with its extensive use of urea formaldehyde-bonded, pressed-wood panelling, and other formaldehyde-containing materials. As a consequence, the Standard was not endorsed by the American National Standards Institute. Since Standard 62-81 failed to gain general acceptance, ASHRAE is in the process of developing a revised standard.

The revised ASHRAE standard probably will propose a single ventilation rate, likely the higher (smoking) rate of Standard 62-81, except in non-smoking settings where it could be lower, and that the IAQ procedure will not set a formaldehyde limit. The Standard also may propose the higher NCRP radon limit of 8 pCi/L, and a lower carbon dioxide limit of 1000 ppm to be used as an indicator for other pollutants that affect comfort. In addition, concerns may be expressed about biological pollutants in HVAC systems, and unvented combustion products, such as those discharged from rink cleaners used in arenas.

In Canada, the 1985 version of the National Building Code requires new dwelling units to have mechanical ventilation systems capable of providing at least one-half an air change per hour during the heating season, based on the interior finished volume of the dwelling unit. This code also draws attention to the possible risk of carbon monoxide poisoning due to chimney backdrafting in new houses stemming from increased enclosure tightness. To help avoid this risk, fireplaces now are now required to have their own supply of combustion air.

POLLUTANTS OF CONCERN

Several individual pollutants and groups of pollutants currently are of particular interest. Concerns about one of these, formaldehyde, have centered on its biological reactivity. Depending on individual sensitivity, formaldehyde exposure can result in irritation to the mucous membranes of the eyes, nose and throat. For example, exposure to levels ranging between 0.4 and 0.7 ppm appear to be the reason for such symptoms as headache, nausea, dizziness, burning eyes and fatigue, according to a recently reported case.

The action of formaldehyde in concentrations as low as 0.05% can cause allergic contact dermatitis. Perhaps the primary concern regarding formaldehyde is that it may be a carcinogen. However, this concern is based on nasal cancers which have been observed in tests on rats exposed to lifelong exposures at comparatively high levels. Epidemiological studies so far have failed to indicate carcinogenic effects on people.

Higher indoor levels of formaldehyde may result from the extensive use of: particle board without a covering layer, UFFI, some sealing materials used for parquet floors, adhesives, varnishes and lacquers, textiles, wall paper, carpets, and curtains. Some of the highest non-industrial formaldehyde exposure levels have been recorded in mobile homes.

Pressed-wood products emit formaldehyde at rates that increase with temperature and humidity, and decrease as the ambient formaldehyde levels increase. Long-term emission decay rates of these materials are not yet available, but emissions are known to continue for years. Studies show that particle board sub-flooring emissions can be reduced by a factor of two or more by covering the floor with polyethylene or vinyl linoleum. Recent studies by NASA, at the National Space Technology Laboratories in Mississippi, have claimed that spider plants can cleanse indoor air of formaldehyde.

The question has been raised as to whether formaldehyde, or some other contaminant related to microbial activity, is the primary cause of UFFI-related health complaints. Further, the question of the relative seriousness of the UFFI health effects is still unresolved. For example, 18 subjects, nine of whom had previously complained of non-respiratory adverse effects from UFFI, failed to show any significant pulmonary function reaction when exposed for 90 minutes to UFFI off-gas (formaldehyde concentration of 1.2 ppm) in a chamber.

On the other hand, a study of occupants in 450 UFFI homes tentatively has indicated the possibility that some individuals suffering from irritation effects associated with the presence of UFFI, possibly due to the slightly higher formaldehyde levels which averaged 0.044 ppm vs. 0.035 for 225 control homes.

Radon is a colorless, odorless, radioactive noble gas produced by the alpha decay of radium. Radium is present in trace amounts in all geologic materials. Radon decays to a series of short-lives (<30 minutes) daughters, exposure to which can eventually cause lung cancer.

Radon gas can enter buildings from the soil through basement cracks and openings, or via untreated well water. It also is emitted by masonry materials. Control of soil radon entering through the basement, often the major source of indoor radon, can be achieved through sealing of the subgrade cracks, such as those between foundation wall and slab, in combination with introducing sub-slab ventilation utilizing, for example, an existing pump and its lead-in water draining pipes. Circulating basement air seems to control radon daughter levels by causing plate-out of the host dust particles. Dust filters and electrostatic precipitators may also help.

UNVENTED COMBUSTION PRODUCTS

Unvented combusion products, including carbon monoxide, carbon dioxide, nitrogen dioxide, and particulates, can accumulate to levels of concern when adequate precautions are not taken. In ice arenas, for example, the hourly cleaning of the ice surface with machines powered by gasoline, propane, or heating oil can raise carbon monoxide levels beyond safe limits if the building is not properly ventilated. Symptoms of carbon monoxide poisoning include headache, fatigue and nausea. In a recent survey in British Columbia, 32 of 64 arenas had CO levels above the B.C. guideline of 25 ppm; 19 arenas had above 50 ppm. While most of the arenas surveyed had ventilation fans, 73% were not being operated. Evidently many managers thought that the accumulation of CO from exhaust is accompanied by an odor and that the fans need be operated only at that time.

Automobile fumes from attached and underground parking garages can be drawn indoors. Gas stoves produce nitrogen oxides, the amounts of which can be reduced through use of new burner flame inserts, elimination of pilot lights, and fumehood exhausting.

With the sealing of housing enclosure leaks, the possibility of chimney backdrafting as a result of the coincident operation of furnaces and fireplaces, or bathroom and clothes dryer exhaust fans, has increased. One study of 100 Canadian homes of various styles and ages showed that 34% were at risk, with depressurization by fireplaces the major contributing factor.

In mechanically ventilated buildings, the fraction of exhaust air recirculated as intake air can change by a factor of five, depending on the use of rain caps, the placement of exhausts and intakes, and the ratio of exhaust to wind velocities. This can be a real concern for buildings with multiple fumehood exhausts, where up to 10% of the exhaust has returned through the ventilation system.

Epidemics of Bacteria Legionnaires' disease, a bacterial pneumonia, have been associated with aerosols from cooling towers and evaporative condensers, and with dusts from landscaping and construction. The recent incident of 37 deaths and 163 persons infected with the disease in a U.K. hospital has been attributed to faulty design. The problem appeared to be with the connection of a vertical drainpipe from a roof top cooling tower to a horizontal drain pipe from an air conditioner on the lower floor. Evidently, at night and on weekends, when the fans were off, polluted water from the cooling tower reached the air conditioner drip trays where bacteria were identified on the mastic around the trays.

Legionella bacteria also can proliferate in hot water systems to be released in showers. Control measures against this latter possibility include maintaining hot water tanks at about 60°C, continuous chlorination and periodic hyperchlorination and, possibly, avoidance of plastic shower hoses.

In general, allergenic and pathogenic biologic organisms can replicate in HVAC system components such as water spray systems, humidifiers, air handling and drain pans, and fan-coil units. Complaints in homes, schools and workplaces of eye, nose and throat irritation as well as fatigue, can be correlated with unpleasant earthy, musty odors produced by abundant saprophytic mould growth.

ISSUES

The emerging IAQ concerns just described have potentially significant implications for Canadians who, because they live in a colder climate, spend most of their time indoors. In addition to potential impacts on the building and health care industries, there are economic implications for the chemical industry, in terms of the use of consumer products and building materials; the tobacco industry and the growing public concern over passive smoke exposures; and the energy industry, in terms of IAQ impacts on building energy conservation and fuel selection. The extent of the implications will depend on three questions:

1. To what extent is IAQ now affecting human health, comfort, and productivity, and what are the future trends?
2. How readily will these trends be adjusted to accommodate IAQ concerns as they become defined?
3. What role will government, industry and the public assume in seeking answers to questions 1 and 2, and in supporting regulatory standards for the indoor environment?

As indicated above, the impact of IAQ on health, comfort and productivity is very poorly understood at present. Certainly Legionnaires' disease, a building-related illness, is known to have caused deaths in hospitals and hotels on an epidemic scale. However, the incidence of this pneumonia, particularly from residential exposures, is unknown and could be under-reported.

While residential exposures to formaldehyde at levels of 0.04 ppm are widespread in Canada, and levels above 0.1 ppm are not unusual in new, tight-enclosure homes, the sensitivity of the population to this irritant is not statistically calibrated.

The incidence of lung cancer due to indoor radon exposures is not known and while small compared to that due to tobacco smoke, the implementation of low-cost construction and ventilation techniques for its avoidance might eliminate a significant number of lung cancers each year.

While many people are no longer willing to tolerate the irritating effects of passive tobacco smoke inhalation, the extent of illness caused by this pollutant continues to be defined with particular concern being expressed for children.

Although there appears to be significant potential for chimney backdrafting in residences, the amount of combustion product backdrafting and related discomfort, illness and death is unknown.

A recent study of 1091 out of 5292 employees in a large Canadian office complex indicated that most employees had suffered from irritation to the upper respiratory tract and eyes which was troublesome at work but not at home.

Symptoms also included headahces, drowsiness, exhausting sleeplessness and irritability, and skin dryness and irritation. As is typical for such symptoms, the etiology of these problems was not established.

In 1984, IAQ investigations were carried out in 94 Canadian federal buildings. NIOSH is doing similar studies. In general, in the majority of office buildings where such complaints occur, the problem is addressed through improvements to the ventilation system. This includes better air circulation, and humidity and temperature control.

In only some of the cases are specific pollutants identified. The re-entry of building exhaust, the entry of motor vehicle exhaust, copy machines, tobacco smoke, and newly glued carpets are among the most frequently identified sources.

Current trends in building design and operation are toward more tightly enclosed, mechanically ventilated structures. The temptation to save energy costs by reducing outdoor air intake in such buildings will be strong, particularly if the associated health risks are unquantified. Increased use of air conditioning in offices and residences reinforces the trend to lower air exchange rates with the outdoors.

As a result of these trends, which will tend to increase indoor pollutant levels, standards developed by ASHRAE and the National Building Code of Canada call for increased mechanical ventilation. Whether these standards can be met in practice, and whether the result will be more or less outdoor air being circulated to occupants when compared to that previously experienced with leaky enclosures and openable windows, is not known.

With respect to one indoor pollutant, tobacco smoke, there is a move to reduce involuntary exposures in office buildings, hospitals, airplanes, hotels, and restaurants by limiting smoking to restricted, separately ventilated areas.

Because of the off-oil emphasis of national energy policies, there is increased use of electricity, gas and wood for heating and cooling Canadian buildings. Use of unvented kerosene heaters for individual room heating has increased substantially. The full impact on IAQ of these changes in mode of heating is not yet known.

There seems to be an increased use of pressed-wood products, such as particle board, in building structures as sub-flooring, in wall finishes, and in furniture. As a result of the formaldehyde concern, particle board emission standards are now in place in Germany.

While the use of synthetic building materials and furnishings, with their associated increases in indoor levels of organic gases may continue to rise, changing fashions -- such as the trend in residences to hardwood floors with centre area rugs, rather than wall-to-wall carpets -- make forecasting difficult.

In general, the relative influence of building materials on the level of air pollutants versus maintenance practices and other sources of pollutants needs to be put in perspective.

With respect to human factors, both the aging of the Canadian population and the trend for more women to work outside the home could influence the incidence of IAQ problems.

The fact that there are so many pollutants indoors, ranging from gases and dust, to bacteria and fungal spores; that buildings, their equipment and their occupants are the pollutant sources; that there are human productivity as well as health concerns; and that the economic impacts of regulation will be large, makes IAQ a difficult issue for governments to address on other than a pollutant-by-pollutant basis. Nevertheless, in Canada and the United States, many federal agencies have become involved in developing coordinated approaches to the issue. However, as a result of recent cutbacks in energy-related research, this activity had to be reduced in Canada.

In addition to the federal government activity in Canada, a workshop of 37 persons from industry, universities, the provinces, and municipalities indicated a desire to see more IAQ research done on a cooperative basis between the building and health disciplines. This group saw the need for a central industry/government coordinating committee and the establishment of centres of excellence.

With respect to indoor pollutant standards, a federal-provincial working group on IAQ is developing residential guideline limits for carbon monoxide, radon, nitrogen dioxide, humidity, ozone, formaldehyde, other aldehydes, and carbon dioxide.

Studies are being conducted in the United States by such diverse groups as the gas, electric, and building controls industries; and states including California and Minnesota; and universities such as Harvard and Princeton.

In projecting those aspects of IAQ on which government attention and action are likely to focus, Douglas and Wildavsky (1982) point out that societal selection of risks to be avoided may depend more on cultural biases than on scientifically based cost-benefit projections.

OPPORTUNITIES

The field of IAQ presents an opportunity for industry and government to work together in several areas of mutual interest. One of these areas would be to develop IAQ screening methods for building materials and furnishings which would help to avoid costly future crises such as those that occurred with asbestos and UFFI. This would minimize the risks to building owners, builders, manufacturers, and governments when new materials are introduced. In the case of UFFI, for example, total remedial costs and property value losses probably exceed $1 billion, yet with the lower formaldehyde levels now being recorded in houses that contain UFFI, the causes for concern remain unclear.

As IAQ standards are adopted by government health authorities for various indoor pollutants, there will be a broad market for related pollutant sensors and pollution-testing services, and government and industry should coordinate their efforts so that these can be put in place in a timely fashion. Coincidently, the demand for low-pollution residences and building materials will increase.

The era of electro-mechanically controlled indoor environments, begun in the 1960s in non-residential buildings with the introduction of air conditioning and large-scale floor plans with offices remote from windows, now is extending to Canadian residences as a result of the revolutionary adoption of polyethylene vapor barriers and flexible sealants to eliminate enclosure leaks. Consequently, there is a growing demand for heat recovery ventilation devices, and sensors and controls that condition indoor environments for energy-efficient housing.

Owing to energy conservation and health and comfort concerns, the demand for air cleaners is growing for the residential and office environments, but there is uncertainty as to the relative merits of the various technologies being employed. The cooperation of government and industry in developing more comprehensive air-cleaner performance standards would provide this industry with an opportunity to market its best products and to increase its market penetration. For buildings in the Far North where energy costs are high, there is a special opportunity to use air cleaners and recirculated air to minimize ventilation costs.

Because of the magnitude, complexity, and newness of the IAQ issue, there are a number of reasons for milti-disciplinary, multi-organizational and multi-laterial cooperation. For example, large-scale scientific surveys of building environments are required to identify pollutants, their sources and building ventilation characteristics, in order to assess the gravity of the IAQ problem.

Such surveys most certainly could benefit from international cooperation so as to share test protocol development costs, and to establish and evaluate a more comprehensive and meaningful IAQ and building parameter data base. With these data on hand, building research priorities could be set, and meaningful clinical and epidemiological studies would follow.

Increased multi-disciplinary cooperation will ensure that health science and building science IAQ research efforts are focussed on common objectives, iterate quickly toward useful results, and remain complementary. Such cooperation will facilitate the study of synergistic effects of groups of contaminants, the development of innovative IAQ measurement devices and indicators, and practicable remedial measures.

The real opportunities, of course, are for the safe-guarding of public health and productivity through the avoidance of building-related illnesses and discomfort, whether these be episodic like Legionnaires' disease, or chronic like the so-called 20th-century disease of hypersensitive individuals.

DETERIORATION OF PARKING GARAGES AND BRIDGE STRUCTURES

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ABSTRACT

To determine the most cost-effective method of repairing a parking garage or bridge structure, and to minimize or prevent subsequent deterioration, it is essential to assess accurately the structure's current condition, to identify all the factors contributing to its deterioration and, where possible, to assess the rate at which deterioration is occurring. This information is required:

- the type of repair work that should be carried out;
- the extent of the repair work required;
- the period of time over which the repairs may be extended.

The techniques and materials used in the structural restoration of reinforced concrete should be selected with care. While there is a general concensus of opinion among engineers regarding the extent of the work needed to restore reinforced concrete to a structurally acceptable condition, there is significant diversity of opinion regarding many of the details of the repair process and the procedures that should be implemented subsequently to prevent or minimize further deterioration.

RÉSUMÉ

Pour déterminer le moyen le plus rentable de réparer un pont ou un parc de stationnement à niveaux multiples et empêcher ou garder au minimum sa détérioration ultérieure, il est essentiel d'évaluer avec exactitude l'état actuel de la structure en cause, d'identifier tous les facteurs ayant contribué à sa deterioration et, dans la mesure du possible, de determiner la rapidite avec laquelle cette détérioration se produit. Ces renseignements sont nécessaires à exécuter;

- le genre de travaux de réparation a exécuter;
- l'éntendue des travaux requis;
- le temps que l'on peut se permettre de prendre pour exécuter les travaux.

Les techniques et matériaux employés en restauration structurelle de béton armé doivent être choisis avec soin. Bien que les ingénieurs s'accordent en général sur l'étendue des travaux nécessaires pour restaurer du béton armé et lui rendre un état structurellement acceptable, les opinions divergent considérablement en ce qui concerne les nombreux aspects du procédé de réparation et des méthodes à employer par la suite pour empêcher sa détérioration ou la garder au minimum.

STRUCTURAL DETERIORATION OF HIGH-RISE BUILDINGS

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ABSTRACT

Although much of the concern about the deterioration of urban structures is now geared towards parking garage deterioration, a number of other building types also are experiencing time-related structural deterioration.

The causes of their problems are not usually as obvious as in parking garages, and diagnostic and repair techniques are not as well-developed. The long-term durability of repair is a critical concern and it is frequently difficult -- but very important -- to judge the cost effectiveness of various options.

This paper reviews the structural deterioration of several buildings. In all cases, the structural investigation and repair techniques are described, as are the defects related to design, construction, and materials. The repairs involved ranged from patching, to adding structural members, to applying cathodic protection. Comments on the durability of the repairs over time also are included.

RÉSUMÉ

Bien qu'une bonne part des préoccupations de caractère structurel exprimées à l'égard de l'infrastructure urbaine tiennent à la détérioration des parcs de stationnement à niveaux multiples,l on relève également un certain nombre d'immeubles dont la charpente se détériore avec le temps.

Les causes de ces problèmes ne sont habituellement pas aussi évidentes que dans le cas des parcs de stationnement à niveaux multiples et les techniques de diagnostic et de réparation à employer ne sont pas aussi perfectionnées. La durabilité des réparations est un souci primordial et, bien que ce soit très important, il est souvent difficile de juger la rentabilité des différentes solutions possibles.

L'exposé porte sur la détérioration structurelle de quelques immeubles. On décrit dans tous les cas les techniques d'examen et de réparation de la charpente qui s'appliquent, ainsi que les défauts de conception et de construction et ceux qui sont inhérents aux matériaux. Les réparations nécessaires vont du raccommodage à l'addition de membres structurels et à l'application d'une protection cathodique. Enfin, on commente également la durabilité des réparations effectuées.

INTRODUCTION

This paper summarizes our experience with concrete deterioration in high-rise structures with exposed cast-in-place concrete elements. The worst deterioration has occurred in concrete containing chloride in significant levels. The features which were found to have contributed extensively to the deterioration are discussed. The examples we have chosen include a pair of 8-storey office buildings in which differences between the design of the two buildings have seriously altered their performance; a 20-storey residential building with serious balcony and column deterioration; and a 17-storey residential building clad with masonry in which the concrete columns behind the masonry have badly deteriorated. The buildings are all in Metropolitan Toronto.

The treatment in each case varied, but at this time no cure for the problems is known.

In each building, at least one other consultant previously had provided the owner with advice based on a superficial investigation, that had failed to identify the principal causes of the problems.

The purpose of this paper, therefore, is to make the engineering community aware of symptoms of concrete deterioration in high-rise structures which should be diagnosed.

BUILDING 1

Description

This 8-storey office building had signs of spalling and cracking of exposed concrete on all four sides. It was built in 1967 and repaired in 1983. Its structure comprises reinforced-concrete columns along the perimeter of the building, a reinforced-concrete core, and reinforced-concrete floor joists spanning from a pair of spandrel beams between the perimeter columns to interior beams along the central core. The system provided clear spans for the full length of the building and from the window line to the elevator core (about 13 m). The exterior spandrel beam system consisted of two beams, one below the windows bending downwards and one at the exterior face of the columns bending upwards, with a concrete deck between them. The floor-reinforcing passed through this deck and hooked into the exterior spandrel beam. The deck was sloped towards the exterior beam. A drainage gutter was provided in the deck slab, and the exterior beam had an upstand to contain the water. Every other column contained a rainwater leader to drain the gutter in the deck on either side of the column. The exposed concrete was painted with a cementitious coating.

Problems

The evidence of trouble with this building was large pop-outs on the face of the exterior beams. In addition, there was horizontal cracking along the tops of these beams. Many of the columns also had vertical cracks at their corners. Rust staining emanated from several of these spalls and cracks.

Investigation

When we were engaged to investigate the condition of the building, the owner had been informed by another consultant that the deterioration was superficial and only minor patching would be required. Consequently, a contractor was engaged to mark all cracks on the building for repair. Upon doing so, the contractor became concerned about the amount of delamination he encountered and advised the owner to seek structural advice. From the swing stage, we recorded the conditions described above, as well as extensive delamination of the deck surface between the spandrel beams. The conditions generally improved above the fourth floor, and were not as serious along the two short ends of the building. We tested the concrete for chloride content at each floor and found significant quantities up to the fourth floor. Our efforts to identify the source of the chloride (either aggregate or admixture) were unsuccessful. We structurally analyzed the floor system and columns to establish the repair alternatives. The floor beams inside were checked for evidence of excessive deflection resulting from the deterioration of the exterior beam, but the cracking we observed seemed consistent with normal flexural behaviour.

Repair Procedure

At the time of this repair (1983) it was generally believed that by reducing moisture access to chloride-contaminated concrete, further delamination could be controlled. We originally proposed moving the window line out to the exterior of the columns to enclose all the concrete and increase rentable floor area. This option was rejected for leasing reasons. We then investigated many coatings which could be used as moisture barriers and cosmetic colourings. An adjacent building with a nearly identical appearance also had to be coated. The relatively high cost of the barrier-type coating made it preferable to use a non-barrier coating where chlorides were not a problem, and we had to find suppliers willing to match the appearance of two different coatings. (One alternative considered was to apply a silane sealer to the chloride-contaminated concrete and paint over it and the rest of the concrete, but silanes were just coming on the market and had no track record). The concrete repairs involved removing all loose concrete from around the reinforcing. The concrete removal was extended along the reinforcing until uncorroded steel was encountered. The exterior beams were shored downwards for three floors where significant loss of bond was produced by the chipping. The steel was sandblasted clean and coated with 100% solids epoxy. Latex-modified concrete was site-mixed and poured into forms.

Observations

Some of the construction details encountered during the repairs were found to have aggravated the deterioration process. The drainage gutter along the top of the deck did not drain effectively, because of the upward deflection at midspan of the exterior beam. The gutter also reduced the cover over the reinforcing in the deck slab. This combination seemed to accelerate the corrosion process along the top of the beams. A plan to completely eliminate the gutters during the repair was abandoned for cost reasons, but a self-levelling caulking was added to the gutters to reduce ponding. (On the adjacent building, which was built 2 years after this one, the deck slabs sloped to a low point mid-way between the spandrel beams and down to the drains). Another detail that was creating problems was the density of vertical steel in the exterior of the columns. Concrete consolidation was poor and there was apparent difficulty in placing the beam steel through the columns. Our calculations showed that there was more steel than necessary in the columns. (The adjacent building had less steel area and fewer bars in the columns, and a smaller proportion of bad concrete.) The spandrel beam reinforcing generally did not have the cover called for in exposed concrete. The hooked ends of the reinforcing from the floor joists also had generally inadequate cover.

Conclusions

These buildings provided an insight into the detrimental effect of chloride in exposed concrete construction. Within the one building, where design details were constant, deterioration in areas without chloride was minor and related to inadequate concrete cover, whereas chloride-contaminated concrete had deteriorated badly. The adjacent uncontaminated building had only cosmetic deterioration resulting from poor concrete cover. We suspect that because of problems encountered during construction of the first building, many design changes were introduced into the second building.

BUILDING 2

Description

This 20-storey residential building is of conventional concrete flat-slab and shear-wall design. It has masonry walls supported in the floor slabs. The walls are recessed at some locations, and the floor slab continued in a straight line to form balconies. The balconies have metal railings connected to the floor slabs with anchor bolts welded to base plates. There is a reglet along the bottom of the outer edge of the balcony slab to act as a drip. At the two short ends of the building, concrete columns were exposed.

Problems

Many of the balconies had cracks along the reglets with evidence of rust staining. The concrete around the bases of the railing posts was generally spalled. Some balconies had leaking cracks.

Investigation

We were engaged after tenders had been called to repair the reglet cracks, the railing base plates, and the leaking cracks. Upon visually inspecting the site, we observed spalled concrete in the lower four floors of the exposed columns. We checked the concrete for chlorides and found significant amounts. We then inspected the balconies and found that the cracks in the reglets were actually the exposed edge of the concrete delaminations. The work was re-tendered to account for the extensive delamination and the repairs required to the columns.

Repair Procedure

The steel along the delaminated edges of the balconies was exposed by chipping, and cleaned by grinding and coating with epoxy to electrically isolate it from the concrete. Latex-modified mortar was poured into forms. The base plates were chipped out, ground clean, coated with a urethane paint, and re-set in mortar. No material was replaced over the base plates. The edges of the plates were caulked.

Observations

Most of the anchor bolts had generally been installed in direct contact with the slab reinforcing. The thin layer of mortar over the base plates was quickly lifted by corrosion of the base plate. Water then gained access to the underside of the plate and the bolt. Corrosion of the reinforcing generally appeared to be very aggressive in the vicinity of the bolts. The reglet on the soffit that was generally directly beneath the bottom reinforcing bar, leaving it with reduced cover.

Conclusions

The deterioration of balconies is a widespread problem. This project is presented as an example of how construction detailing can aggravate the naturally corrosive effects of chlorides in concrete. The repairs have removed all concrete which was in danger of falling off, but no fundamental protection against corrosion of adjacent reinforcing has been installed. Continued monitoring will be required on this building until a stable condition has been reached or an economical treatment method developed.

BUILDING 3

Description

This is a 17-storey residential building constructed in 1965. It has reinforced-concrete floor slabs, columns, and central core. The wall cladding is masonry, comprising 4-inch brick with 4-inch block backing connected by brick headers, and vertical strip windows with aluminum spandrel panels. There are many recesses in the walls. There are 20 perimeter columns at the edge of the floor slabs. The block backup stops at these columns. The brick cladding is connected by dove-tail anchors to the columns. At every floor slab there are shelf angles to support the brick.

Problems

The brick cladding of this building had vertical cracks at several corners. The problem was attributed to high stresses in the brick caused by concrete frame shortening. As the problem appeared to be fairly local, the cracked bricks were removed and replaced with sound bricks. Photographs taken during this operation showed that the column behind the cracked brick also had cracks. We were asked to investigate this condition.

Investigation

The owner of this building knew that calcium chloride had been added to the concrete for the first 12 floors to facilitate winter construction. Our analysis of photographs was that serious delamination had taken place. We had the bricks removed from one column up to the fourteenth floor. Deep delamination was found at about half the floor levels. In addition, the dove-tail anchor slots, which are fabricated from thin galvanized steel, had corroded and caused spalling of some of the column corners. Chloride contamination was found to be general below the thirteenth floor.

Repair Procedure

The concrete delamination repair involved removing the delaminated concrete and adjacent concrete until uncorroded reinforcing was encountered. The steel was sandblasted and epoxy-coated. Polymer-modified mortar was placed in the patch. The owner wanted the masonry replaced, which meant that further deterioration of the concrete would not be visible. It was apparent that corrosion would continue unless a treatment was applied, so consideration was given to two alternatives: sealing the column or applying cathodic protection. Sealing the columns would have reduced absorption of water by the column, but this is not a sure method of preventing corrosion. Cathodic protection for reinforced concrete structures uses an impressed current between a conductive layer on the concrete surface and the embedded reinforcing. The purpose of the impressed current is to eliminate the local potential differences along the reinforcing which cause the galvanic corrosion associated with chloride contamination. The systems available for concrete all have short histories of application, but provide the only known method of controlling corrosion in contaminated concrete. We therefore installed a trial system on one column and shall monitor it for 2 years.

Observations

The concrete repairs occurred primarily above and below the floor slabs. It is likely that the steel in the interior floor slab acts as a large cathode to the anode exterior steel of the column. One of the unknown factors about cathodic protection is how it will affect steel connected to the protected element, but contained in elements not coated with the cathodic coating. We also had to check into the amount of chloride that would be liberated from the concrete by the process; obviously the owner was concerned for the safety of the residents. For various reasons we concluded that this would not be a problem.

During the concrete repairs we discovered that the three column ties called for within the splice length, between the base of one column and the reinforcing from the column below, frequently were missing. This necessitated adding straps around the column. Particular care had to be taken with the design of the tie system to ensure that no path for current was provided between the surface coating and the reinforcing. (The same condition applied to the shelf angles supporting the masonry).

Conclusions

It is apparent from this example that chloride-contaminated concrete can deteriorate even when not directly exposed on the exterior of the building. It is important to recognize signs of corrosion in all elements of a structure under investigation to ensure that serious structural problems are not hidden behind cladding. It also is important to analyze the exposed elements of a structure undergoing repair to ensure that the as-built condition meets the requirements of the design. If not, structural analysis of the existing condition is required to establish the extent of reinforcing which will be required.

GENERAL CONCLUSIONS

The durability and, indeed, safety of our stock of buildings is now a matter of serious concern to building owners, the public users of buildings, and government authorities. Whereas much of the structural concern currently is geared towards parking garage deterioration, our firm is encountering a number of other buildings with structural problems. The causes of these problems are not usually as obvious as in parking garages, and diagnostic and repair techniques are not as well-developed. Long-term durability of the repairs is a critical concern and it is frequently difficult, but very important, to judge the cost effectiveness of various options. The repairs can range from patching, to adding structural members, to applying cathodic protection.

THE REALITIES OF URBAN INFRASTRUCTURE RENEWAL

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ABSTRACT

The politican must balance efforts regarding urban infrastructure renewal between the reality presented by experts and the perception of the problem by the public. In the latter case, the public's preception is limited by the invisibility of many of the infrastructure problems. Repair of infrastructure is falling behind and help is needed to restore the quality of the urban environment.

RÉSUMÉ

Quand vient le moment de renouveler l'infrastructure urbaine, l'homme politique doit trouver un compromis acceptable pour tous entre la réalité dépeinte par les experts et celle qui est perçue par le public. Or la perception du public est gênée par l'invisibilité de nombreux éléments de l'infrastructure. La réparation de l'infrastructure prend du retard, et il faut obtenir de l'aide si l'on veut rétablir la qualité du milieu urbain.

I am here before you because I am a politician with some experience, and some successes, in the area that you have gathered to discuss -- Canada's national economic crisis from my point of view -- the crisis of our crumbling municipal infrastructure.

A politican has a very interesting role in this area, because he or she is halfway between the reality and the perception: the reality that you, the experts, know, and the perception that they, the public, have of the problem and of its consequences for them in the future. The Canadian public is only just beginning to perceive the painful realities inherent in the infrastructure problem, and in my talk today, I will outline how Canada's politicians are dealing with the enormous task of "waking the country up" in this area, and I'll try to give you some sense of the future of this issue from a political perspective.

First, let me deal with the realities as I know them for the 600,000 people of Edmonton. I will talk about the realities of what my technical experts tell me, about the realities of what we, as municipal politicians, have done both in Edmonton and across Canada. Finally I will deal with public perception and what I think needs to be done to get a grip on the solution to the problem we all know we have.

My experts tell me we need $2 billion worth of replacement work to the infrastructure of my city (See Attachment I). Roads, sidewalks, water and sewer lines, bridges and the like. This is the Cadillac fix. We could probably do with a bit less, but let's use the $2 billion figure for now.

Two billion dollars. That is equal to nearly 18 months of our total city capital and operating budget (and bear in mind that we have Canada's largest municipal budget because we operate the country's fifth largest telephone company, Alberta's second largest power generation company, Canada's 10th busiest airport and, unlike some other cities, our own transit system).

Two billion dollars is 10 years' worth of our entire business and residential tax levy!

If we were to borrow, on our own, $200 million over each of the next 10 years to finance our Big Fix (Attachment II), the people of Edmonton would face tax increases of up to 116% in the 10th year, or with a 20-year amortization period, tax increases averaging nearly 60% over each year of the 20-year period. And those figures don't take into account the inflation we would have to work into our tax base over the years.

There is nothing different in our situation; every other city in Canada faces the same scope of problem. And the reality is obvious: no citizen is going to stand for such huge municipal tax increses, and no city has the necessary resources to handle such a fix on its own. Even if we were to settle for a less-than-Cadillac fix, the cost to municipal governments, which are limited to property and business tax bases, is wholly out of sight.

With that in mind, let us look for a moment at the extent of what we in Edmonton been able to accomplish. Although it is a record I am proud of, I think you will see, as I describe what we have done, how much more there is to do before we have come to grips completely with the enormity of the problem facing us.

A few years ago, Edmonton City Council implemented a special development levy on new construction to pay for sewer line upgrading (Attachment III). In retrospect, since it imposed on only a few individuals and developers relatively huge costs, it often made the economics of redevelopment unworkable. I know personally of average income families, people who had saved for years to afford a new home or a major addition to an existing home, who were hit with a $5,000 levy.

Within a few months, under great pressure from our electors, council reconsidered the idea, and in its place imposed an across-the-board monthly levy on our utility bills, amounting to something like $1 a month for a combined sewer upgrading program -- a program which will raise $4.5 million annually to upgrade the old combined sewer systems in some of our older neighborhoods (Attachment IV). In 1986, we also began a percentage-rate cast-iron watermain upgrading charge on utility bills, based on the amount of water used (the amount varies between 25 cents and $1 on a monthly bill), and to date this has generated $4 million for cast-iron replacements.

We have used snow removal savings of $1 million to increase our street maintenance program (See Attachment V). We have changed our financial policies in such a way that money previously restricted to new capital construction projects now can be used for reconstruction. This, I must say, has been assisted by the slowing down of the previously supercharged growth rates we experienced in Edmonton as a result of the oil boom of the late 1970s. This new financial policy has resulted in 70% of our capital roadway budget now being used for reconstruction.

But as a politician, I have not stopped there, for I know that only provinces and the federal government have the resources, the income sources, necessary to tackle the problem effectively.

For more than 3 years now, I have been highly active in Canada's Big City Mayors' Caucus, a very effective arm of the Federation of Canadian Municipalities. The caucus started with the study showing that larger Canadian cities were collectively in need of more that $12 billion worth of infrastructural repairs. That figure, with inflation and the new federal tax on construction materials, is now approaching the $15 billion mark.

Prestigious consultants, belonging to a company often hired by the federal government itself, were asked to assume that all three levels of Canadian government would contribute equal thirds over a 5-year period to a major, nation-wide effort to modernize our urban infrastructure on the scale identified by the original study, and to analyze the impacts of such a program on both national and provincial debts, and on employment. The consultants stated categorically that, assuming even the most conservative impacts, such a program would create 300,000 productive new jobs in Canada over the 5 years, and yet have no net impact on national or provincial debts, since it would offset costs with increased taxes collected on incomes, profits, and construction materials. In less conservative scenarios, the consultants even saw a net reduction in the provincial and federal debts as a result of such a program.

One of the major problems associated with infrastructural replacement programs is the invisibility of the problems: for the most part they are literally buried underground. As a result, it is a hard political sell in most economic times. How can you convince someone to pay extra for something he or she can not see? In normal or good times, its much easier just to patch up the cracks in the system than it is to convince the public to bite a bullet.

But times are tough. In my city alone, there are more than 50,000 people pounding the streets looking for work, and the situation, while may not be as extreme in other locations, is basically the same across Canada.

We in the Big City Mayors' Caucus thought we were really on to something, given the obvious jobs-jobs-jobs aspect of the solution we had developed. We thought we had something politically saleable, something the other levels of government would jump at. We first approached senior members of the federal government. They were "interested", but since municipalities are legal creatures of the provinces, we were told to get the provinces onside before the federal government would consider our proposal.

Our collective action crystallized in the FCM's Urban Infrastructure Repair Program proposal being discussed by Canada's provincial municipal ministers. But there were problems. While all provinces but Alberta and B.C. were in favor, we had been told that all 10 provinces had to be in agreement before the federal government would entertain participation. Nearly concurrently, a new leader of Alberta's government party was chosen, Don Getty. In my first meeting with the new premier, he asked me what my top five priorities were. Number one was the infrastructure program. Almost overnight, Alberta was onside. Similarly, when B.C.'s Government party subsequently chose a new leader, that province, too, agreed to participate in the program.

One might expect the next major event to focus on the federal government. But before the Big City Mayors' Caucus could meet to plan its strategy, the premier of Alberta proved that he had listened well when he announced a $500 million, 8-year job creation program focused on urban infrastructure. The program, called the AMPLE program (Attachment VI), is to be financed through savings on lower present-day interest rates obtainable on provincial borrowings for municipal purposes. The City of Edmonton's share of the program is approximately $125 million, starting out with $8 million this year and gradually increasing throughout the program's life. Initially, we will be using the money to totally refurbish three neighborhoods, with more to come in the future.

Despite the pleasing number of zeroes in that provincial program, and even though we are lucky in Edmonton that we have a council that is prepared to bite off what it can chew in this economy, and that we have an enlightened provincial government, we are still talking peanuts. Remember that Edmonton needs up to $2 billion worth of improvements.

Obviously, we have on our hands the makings of a national economic disaster -- the equivalent of taking out a cash advance on your VISA card so you can make a deposit in your savings account. In Edmonton, on a very cold winter day, we spend up to $180,000 a day alone fixing as many as 75 watermain breaks, money that is literally disappearing from our economy.

Multiply that figure across the nation, and you will see clearly that we as a nation are literally dumping millions of dollars daily -- that is, billions of dollars a year -- into rag-tag patchwork repair of aging water and sewer lines, into the simple filling of potholes. In my opinion, that is an inexcusable, low-tech, menial, inefficient use of our country's financial resources. This money that is vanishing before our eyes could instead be used productively, for example, in the research and development we need to keep abreast of the rest of the world's economies, in the opening up of new world markets for the products that this R & D would stimulate, in making Canada into a truly great trading nation. This money could be used instead in the creation of hundreds of thousands of high-income jobs that would come with such an investment. We have the ability to use badly-needed, short-term, low-tech jobs as an investment in the efficiency of our entire society, and to turn that efficiency into an economic legacy for our children.

The focus now is on the federal government, for it now stands alone as the crucial key to our potential to turn the inefficiency we suffer at the base of our society -- on and under the very streets we travel -- into global-level efficiency, into mastery of the free-enterprise world of international competition. The federal government has within its grasp the ability to solve our short-term national unemployment curse, to at least hold its ground with regard to its admirable priority on the national debt, and to start the Canadian people on a long-term march toward economic emancipation all at the same time.

The federal government could, if it wanted, agree with the recommendation of the MacDonald Commission on the Economy and grant cities a new constitutional niche, where they would enjoy a specified share of the myriad of revenue sources available to the provinces and to the federal government. That would be great, because then cities and provinces could all march off together and tackle this massive problem, but I think this solution is highly unlikely to be adopted. Or, the federal government simply could agree that a national partnership is an economic necessity from both short- and long-term points of view, and catalyze the partnership with one very easy step: the word "Yes".

Canada is a young nation; it is without experience in the maintenance of a national infrastructure on the same level that other, more economically successful nations have. I believe that prudent infrastructure maintenance has been a major key in the success of those other nations.

I would be pleased to see that my government has the wisdom to join that international club, far more pleased than if the third option available to the government is the one chosen; for that third option, the option to do nothing, would be identical to a life sentence of progressively higher inefficiency, national economic decay, international "falling behind". A decision to do nothing would create a Canada that I would not be very proud of.

On a positive note, I can assure you that Canada's Big City Mayors, with the assistance of Canada's provincial municipal affairs ministers, will continue their lobby on the federal government with increased vigor, now that we have two of the three necessary levels of government unanimous in their support of the replacement program proposal.

I am a positive kind of person, and I believe that the federal government will see the wisdom of this program we have proposed. My feeling is that they'll see the wisdom in time for the 1988 election, and that by 1989 Canada's cities can begin the task of entering the 21st Century with our houses well in order.

ATTACHMENT I

CITY OF EDMONTON/OVERVIEW FROM OFFICE OF THE CITY MANAGER

Estimated Infrastructure Repairs (according to a 1983 FCM Survey)

Roadways, Sidewalks, Curbs and Gutter	$ 580,000,000
Bridge Structures	190,000,000
Sewer & Water Systems	1,230,000,000
	$2,000,000,000

Infrastructure repairs, if completed, would cost almost $400 for every minute of the next ten years.

ATTACHMENT II

CITY OF EDMONTON

Estimated Financial Impact of Infrastructure Program
10 Year Period, $200 Million Per Year

					Effect of the Program on an Average House (4)	
Year	Annual Expenditure	Annual Debt Costs (1)	Normal Municipal Tax Levy Base (2)	Debt Costs As a % of Tax Levy (3)	Normal Tax Levy +	Tax Levy for Debt Costs (5)
		(millions of dollars)		(whole dollars)		
1987	200	33	197	16.5	1,146	189
1988	200	65	205	31.8	1,192	379
1989	200	98	213	45.8	1,240	568
1990	200	130	222	58.8	1,290	759
1991	200	163	230	70.6	1,342	947
1992	200	195	240	81.5	1,396	1,138
1993	200	228	249	91.4	1,452	1,327
1994	200	260	259	100.4	1,510	1,516
1995	200	293	270	108.7	1,570	1,707
1996	200	325	280	116.1	1,633	1,896
1997		293	291	100.6	1,698	1,708
1998		260	303	85.8	1,766	1,515
1999		228	315	72.3	1,837	1,328
2000		195	328	59.4	1,910	1,135
2001		163	341	47.8	1,986	949
2002		130	354	36.7	2,065	758
2003		98	368	26.6	2,148	571
2004		65	383	16.9	2,234	378
2005		33	398	8.2	2,323	190
Total	2,000	3,255	5,446	59.8 (average annual percentage)	31,738	18,958

Assumptions/Notes:

(1) These debt costs, which would have to be raised in addition to the tax levy shown in the column to the immediate right, are based on a maximum ten year debt term (City Policy) and an estimated 10% rate of interest.

(2) Municipal taxes increased 4% annually for inflation.

(3) Percentage impact of debt costs on municipal property taxes.

(4) Defined house as per Planning and Building Department's Property Tax Survey (December 11, 1986). Property tax on this house for 1986 was $1,113 and is assumed to increase by 3% for 1987 ($1,146).

(5) The tax levy shown in the column to the immediate left would have to increase by this amount to pay for the debt costs of this program.

ATTACHMENT III

RELIEF SEWER FINANCING: REDEVELOPMENT LEVY

The combined sewer district of the City of Edmonton comprises about 4500 hectares of the central core of the city (the oldest part of the city) as shown in the enclosed map (Enclosure I). These sewers collect and carry both sanitary and storm flows generated within the area.

In general, these sewers are over 25 years of age (some are as old as 75 years) and require capacity upgrading to meet increased loadings due to extensive redevelopment within the area as well as higher service level expectations of the customers. Minimizing the potential for basement flooding due to sewer back ups during heavy rains is the most important benefit expected by the customers in this area.

Recognizing the need to implement a program of constructing relief sewers in these oldest areas of the city, in 1972 city council, by resolution approved levying of sewer charges on redeveloping properties within this area to pay for these works. The charge was calculated using a uniform unit rate per assessable frontage length of each property.

The authority of council to charge by resolution rather than by bylaw as prescribed by the Municipal Taxation Act was successfully challenged in the courts. As a result, in 1978 city council authorized four bylaws to cover retroactively all charges levied from 1972, as well as to continue the charges on future redeveloping properties. These bylaws also approved a 22 year (1978 to 2000) construction schedule covering the total combined area.

Due to the prevailing high level of redevelopment in a booming economic environment, this levy generated funds in excess of the requirements for annual expenditures on the work until the end of 1982. Therefore, in 1982, city council approved an accelerated pace for the program to provide early relief to the South-East areas of Holyrood, Ottewell and Forest Heights, where extensive floodings had occurred during a severe storm in the summer of 1981.

Shortly thereafter, a major downturn in the economy took place and these levies were questioned. The unit rates had increased from about $51.30 per assessable foot in 1978, to $90.10 per assessable foot in 1985. By the end of 1985, the total accumulated revenue from the levy was about $29.7 million, whereas the total of accumulated expenditures under the accelerated program was about $41.5 million.

The levy was perceived as unfair by private homeowners re-developing their properties. During the economic boom times prior to the early 1980's, re-development in most cases consisted of the demolition of private residences for the building of apartment or commercial complexes. If, for example, six homes were bulldozed to build a $5 million apartment complex, the levy was approximately $20,000, a fraction of one percent of project cost. On the other hand, when the economy took a downturn and homeowners were upgrading their existing homes or razing them to build new ones, the levy was $6,000 or more on a $50,000 home, 12% of project cost. Citizens felt this was unduly harsh, and politicians of the day agreed.

As a result, a series of new proposals, revisions and alternatives were considered by city council to address the financing issue. This process culminated in the November 26, 1985 council resolution which established a city-wide utility surcharge as a replacement for the redevelopment levy effective January 1, 1986 to be applied over a 15-year period to complete the balance of work under the program. This resolution also upheld the collection of all redevelopment levies charged until December 1, 1985. This new program, (ie. the city-wide utility surcharge) is described in Attachment IV.

ATTACHMENT III

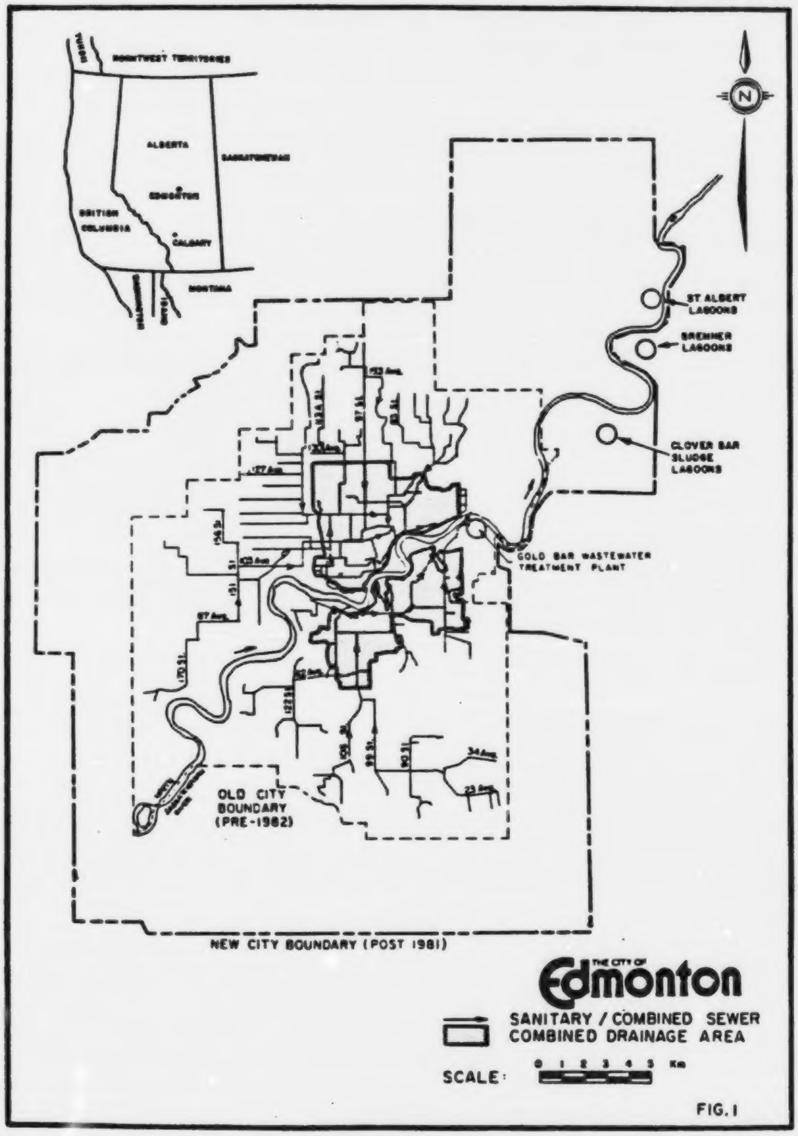
NORTHWEST TERRITORIES
YUKON
ALBERTA
SASKATCHEWAN
EDMONTON
BRITISH COLUMBIA
CALGARY
MONTANA
WASHINGTON
IDAHO
N
ST ALBERT LAGOONS
BRENNER LAGOONS
CLOVER BAR SLUDGE LAGOONS
GOLD BAR WASTEWATER TREATMENT PLANT
153 Ave.
127 Ave.
97 St.
82 St.
156 St.
151 St.
170 St.
87 Ave.
122 St.
105 St.
99 St.
90 St.
34 Ave.
23 Ave.
OLD CITY BOUNDARY (PRE-1982)
NEW CITY BOUNDARY (POST 1981)
THE CITY OF Edmonton
SANITARY / COMBINED SEWER
COMBINED DRAINAGE AREA
SCALE:
0 1 2 3 4 5 Km

FIG. 1

ATTACHMENT IV

RELIEF SEWER FINANCING: CITY-WIDE UTILITY SURCHARGE

On Novemter 26, 1985 Edmonton City Council approved a city-wide utility surcharge effective January 1, 1986 to replace the sewer redevelopment levy.

The objective of this surcharge is to collect approximately $4.5 million annually for the period from 1986 to the year 2000 so that the combined sewer upgrading program in the city can be completed at a total estimated cost of $67 million.

The implementation strategy is to cover the expenditures on a "pay-as-you-go" basis thereby eliminating debt charges. This funding program also has eliminated the additional heavy burden imposed on redeveloping properties through the redevelopment levy and recognizes that the total community, as a single user group, must play an active role in sewer infrastructure rehabilitation works in different parts of the city as the systems become older.

This surcharge is being collected through the utility bills of customers. All residential customers are assessed a flat rate of $2.00 per month and non-residential customers pay 7 cents per cubic metre of water consumption , to a maximum of $25.00 per month. All those properties which had been assessed the sewer redevelopment levy (in effect from 1972 to 1985, described in Attachment III), are completely exempted from this charqe.

In 1986, about $4.4 million was collected under this program and, as directed by council, these revenues were spent on relief works within the combined sewer district. Council also approved the priority ranking of the sub-areas based on an engineering evaluation of the existing systems and historical experiences of floodings. If overexpenditures occur in a given year, the shortfall will be met by short-term borrowing and reduced expenditures in the following year.

From 1972 to the end of 1986, about 50% of this 4500 hectare area has been provided with relief sewers at a cost of about $46 million, and the incidences of sewer failures and the frequency of basement flooding have been reduced considerably in these areas for comparative storm conditions. With this new city-wide, pay-as-you-go funding source in place, council is confident it can complete these rehabilitation works without increasing the city's debts or imposing severe financial burdens on small groups of customers.

ATTACHMENT V

APPLICATION OF SNOW REMOVAL SAVINGS

During the first half of 1986, a saving of $1.4 million was being projected in the City's snow removal budget. As a result, city council allocated $1 million of the projected saving to roadways for rehabilitation work. This money was used in the following manner:

1. Resurfacing work was completed at ten locations at a cost of $573,000. This included:

Surface Milling	$146,000
Resurfacing	354,000
Lane Marking	73,000

2. Road base repair was completed at 73 locations at a cost of $382,592.

ATTACHMENT VI

Details of Provincial AMPLE Grant Program Relative to the City of Edmonton Infrastructure Program

General

The Alberta Municipal Partnership in Local Employment (AMPLE) Program was announced in April 1986 by the Provincial Government.

AMPLE is an unconditional per capita grant which is to be paid automatically to Alberta muncipalities in 1987 and subsequent years until a total payment of $500 million has been made.

The City of Edmonton, representing approximately 25% of the provincial population, will receive about $125 million over an estimated period expected to exceed 8 years. The announced payment for 1987 only is $12.78 per capita which amounts to $7.3 million for the City of Edmonton.

Source of Funds

The Alberta Muncipal Financing Corporation (AMFC) provides loans to municipalities for periods up to 25 years. AMFC finances many of these loans using short-term issues.

During the period of rising interest rates (1978 to March 31, 1986), the Alberta Government provided an Interest Rate Stabilization Program which rebated to municipalities for eligible debt with AMFC interest payments in excess of rates varying from 8% - 11% for the term of each debenture, or reduced to five years for certain debentures issued after March 31, 1983.

Commencing in September 1986, and expected to continue until 1989, AMFC began refinancing certain of its short-term issues at the greatly reduced current interest rates. The Alberta Government announced a program effective January 1, 1987 to transfer the interest savings to muncipalities by reducing the interest rate on all AMFC debt to a maximum of 14%.

The reduction of AMFC interest rates results in savings in the Alberta Government Interest Rate Stabliziation Program which is being used to fund the AMPLE Program Grants.

Use of Funds

The AMPLE Program is unconditional, however, as implied by the title, it is expected that the grants will be used for programs which will generate or maintain employment.

The City of Edmonton intends to use the funds for its Infrastructure Repair Program. The 1987 $7.3 million grant has been budgeted for as follows:

Parks & Recreation Facilities Repair & Upgrading	$1.4
Other Civic Properties Repairs & Upgrading	.6
Water lines, Sanitary & Storm Sewer Rehabilitation	4.4
Roadway, Sidewalk, Curb & Gutter Repairs	.9
Total	$7.3 million

Future Funds

As AMFC continues their refinancing, further interest rate reductions will occur and the annual amount of grant funds will increase until the $500 million AMPLE program is completed. It was originally indicated that an 8 year term would complete it, but budget restraints have caused the Alberta Government to reduce grant funding which will probably result in a longer period for this grant program.

THE RENEWAL OF URBAN INFRASTRUCTURE IN MONTREAL

M. Michael Fainstat
president du Comite executif de Montreal

ABSTRACT

Montreal's urban infrastructure and their need for renewal and upgrading present a formidable challenge in future years. This challenge will have a serious financial impact on Montreal and other municipalities if governmental cost-sharing programs are not instituted. At the same time, we envisage a very positive impact on economic growth if Canadian municipalities proceed with intensive infrastructure construction programs.

RÉSUMÉ

Le renouvellement et l'amélioration des infrastructures de Montréal constituent un défi de taille, qu'il nous faudra relever au cours des années qui viennent. Cela aura de graves répercussions sur la situation financière de la ville de Montréal et d'autres municipalités, si on ne met pas en oeuvre des programmes gouvernementaux de partage des coûts. Toutefois, cela pourrait être aussi très propice à la croissance économique, si les municipalités canadiennes étaient en mesure d'exécuter des programmes intensifs d'aménagement d'infrastructures.

EVALUATION OF MONTREAL'S SITUATION

Before discussing these issues, I would like to present our evaluation of Montreal's situation regarding urban infrastructure. Since 1950, Montreal has experienced major growth, especially in its downtown core. If you have travelled to Montreal lately, you may have noticed that major building projects are underway, causing a detrimental impact on vehicular traffic. These large construction projects are also causing new demands for water, drainage, sewage disposal, and electric power.

Like most major cities in Canada, Montreal has experienced rapid growth in the housing industry resulting from federal and provincial economic policies during the late

1970s and early 1980s. These policies were implemented largely to offset the economic crisis, and Montreal had to build new infrastructure to meet this housing growth. At the same time, interest rates were increasing rapidly, so that the City had to restrain its borrowing and spending. All this led the previous administration to neglect the renewal of old infrastructure in favour of allocating funds for new development projects. Montreal has reacted on an ad hoc basis to the immediate needs imposed by specific projects of private and public corporations.

A modern administration cannot function without a medium- and long-term strategy. It must establish clearly defined goals, and set out realistic, achievable policies that have public support.

Montréal jouit d'un grand nombre d'infrastructures urbaines dont elle peut à juste titre s'enorgueillir. Avec les débuts de l'industrialisation, de nombreuses infrastructures d'égoûts, d'eau potable et de transport ont été construites. Ces équipements tiennent toujours, un siècle plus tard, il faut rendre hommage aux concepteurs et constructeurs de ces infrastructures qui ne disposaient pas de la téchnologie d'aujourd'hui. Depuis les 25 dernières années, Montréal s'est doté d'un système de transport en commun qui à acquis une réputation internationale, particulièrement son métro. L'usine de production de l'eau Charles Desbaillets est également un des joyaux de nos infrastructures urbaines. Malgré la qualité de nos infrastructures, force nous est de reconnaître qu'elles prennent de l'âge et qu'une politique d'entretien rigoureux doit être établié pour être en mésure de les conserver le plus longtemps possible.

PUBLIC THOROUGHFARES

In the category of public thoroughfares, we shall look into four components:

- paving of streets and sidewalks;
- bridges and tunnels;
- traffic lights; and
- street illumination.

Paving of Streets and Sidewalks

Regarding the paving of streets and sidewalks, the City of Montreal has to plan on an investment of $32 million if it wishes to upgrade the system. The road system is in good shape. It has been upgraded in the last couple of years: in 1985, 80% of the roads were judged by our Public Works Department to be satisfactory to excellent, compared to 62% in 1981.

Nearly all our sidewalks are built of concrete, and about 90% are in fairly good condition. Nevertheless, our grid of roads and sidewalks is so extensive that an intensive renewal program would require more than $30 million per year for the next 10 years. This amount would enable the City to stem the increasing deterioration.

Bridges and Tunnels

The bridges and tunnels in the City of Montreal require also a lot of maintenance and renewal. Our first estimate is that it would require $62 million just to put them back into reasonable shape.

In the City of Montreal alone, there are 291 structures of which 45% were built before 1940. Negligible work has been done since their construction. We must anticipate that major rehabilitation work will be needed in the coming years, and in some cases, structures will have to be replaced completely. If we were to replace all 291 structures at once, the cost would be about $1 billion, hence the importance of a regular and disciplined maintenance program.

Traffic Lights

In Montreal, there are 1,400 road crossings equipped with traffic lights. This system is considered rather outmoded and inadequate for today's growing traffic problems. The system in place has no data processing capabilities that would enable greater flexibility for rush-hour traffic. To modernize the system with the latest computerized technology would require an investment of more than $17 million over the next 8 years.

Illumination

Before 1982, most street lamps used mercury. At present, the City of Montreal is converting to high-pressure sodium lamps because of operating economics; high-pressure sodium lamps use 40% less electricity for the same output. Our specialists are of the opinion that a massive conversion of the system could be financed through the savings of electricity costs which is what the City of Edmonton seems to have done lately. More than $1 million could be saved each year.

WATER SUPPLY SYSTEM

Water Intake

Water consumption is increasing rapidly in Montreal. Though we are still in a surplus position, we estimate that by the year 1990, we will reach our maximum capacity for the existing water intake. We could use an old intake which has not been in operation for years. We also could increase the capacity of the existing intake, or else, we could build a new one at a cost now estimated at $53 million. A decision will have to be made soon.

From the water intake, a feeder canal more than 8 kilometres in length built in 1913 needs urgent repairs. To repair this infrastructure, $1.7 million would be needed.

Water Production Facilities

Montreal has invested in production facilities during the last few years, but another $10 million will have to be spent to increase productivity. For adequate maintenance, an expenditure of $17 million is required during the next decade. Total investment should therefore be approximately $27 million

Distribution of Water

Montreal has a subterranean water distribution grid that totals 2,500 kilometres. In some areas, the diameter of the conduits is such that adequate water pressure is unattainable. More than $5 million would be needed to enhance the piping system in three or four districts of Montreal.

DRAINAGE SYSTEM

The drainage system is almost as extensive as the one for the distribution of water. In fact, its length is equal to the distance between Montreal and Winnipeg. There also are 23,000 wells that provide access to the system. During heavy rains, some parts of Montreal are prone to flooding. During the last 6 years, almost 800 claims for compensation have been forwarded to the City of Montreal. Forty million dollars would be required to correct the situation.

BUILDINGS

The City of Montreal owns no fewer than 630 buildings. Replacement costs of these buildings would be about $1.2 billion. Just for the urgent maintenance of these buildings, we need to invest $1.5 million. Benefits could result from this investment: $400,000 could be saved in energy costs alone. Windows have to be replaced at a cost of $340,000 each year. To be sure that these buildings conform with the existing regulations, the City would have to invest $6 million a year for the next 5 years.

PARKS

The City of Montreal has 560 parks of which 80% are considered to be in satisfactory to excellent state. To upgrade the parks that are less than satisfactory, a sum of $17 million would be required.

AUTRES ÉLÉMENTS À CONSIDERER

J'aimerais également vous mentionner sans entrer dans les détails d'autres domaines qui nous créeront des exigences en termes de recherche de nouvelles solutions téchniques, soit la gestion des déchèts solides, du transport en commun, des neïges et des eaeux usées.

Solid Waste Management. La gestion des déchèts solides pose un défi important dans la mesure où les contraintes environnementales obligent les municipalités à trouver de nouvelles méthodes plus en accord avec la protection de la qualité de vie des citoyens.

Snow Removal. Le déneigement pose sensiblement la même question. Le tiers de la neïge récueilli à Montréal est déversé dans le Fleûve St.-Aurent. Des études environnementales ont été commandées récemment pour évaluer en détail les impacts sur la qualité de l'eau. Si la ville devait réduire la quantité déversée, elle dévra alors soit trouver de nouvelles méthodes ou alors acheminer un plus grand volume vers l'usine d'épuration des eaux.

Public Transport. Le transport en commun qui relève de la Communauté Urbaine de Montréal fait l'objet d'un important programme d'entretien des infrastructures qui comme je l'ai dit précédemment représente un des éléments essentials de la qualité de vie des citoyens et citoyennes de Montréal. Pour les trois prochaines années, un

budget de 135 millions de dollars sera consacré à l'entrétien des équipements de métro et d'autobus.

Wastewater Treatment. Enfin, quant au traitement des eaux usées, le gouvernement du Québec et les municipalités de l'île de Montréal sont engagés dans un programme visant à être en mésure en 1990 de trâiter toutes les eaux usées. Ce projet représente un investissement d'environ 1 milliard et demi de dollars. Le gouvernement du Québec offre des subventions jusqu'à concurrence des deux-tièrs du coût des intercepteurs et jusqu'à 90% du coût des travaux a l'usine d'epuration.

CONCLUSIONS

L'examen de notre situation montre que le bilan de la ville de Montréal correspond en gros aux principales conclusions auxquèlles la fédération Canadienne des municipalitiés en est venue dans ses travaux.

For the next 3 years, the City of Montreal will invest more than $150 million each year in its regular capital expenditures program. If a major effort of renewal is to be undertaken, $450 million would have to be spent within the next 5 years. Each year, $90 million would have to be added to the actual capital expenditure budget. It would boost the annual capital expenditure budget from $150 million to almost $240 million: an annual increase of almost two-thirds!

À Montréal, comme ailleurs, dépuis 15 ans, le financement fédéral, provincial et municipal n'a pas été suffisant pour que soient entreténues convènablement nos infrastruuctures anciènnes.

L'ampleur des investissements, les répercussions sociales, écologiques et économiques des travâux à entreprendre conduisent tout droît à la conclusion que les villes seules ne pourront assumer toute la charge financière d'un vaste programme de rénouvellement et de modernisation de leurs infrastructures éssentièlles.

Des gouvernements du Canada et du Québec, nous attendons deux choses:

- Prémièrement, qu'ils reconnaîssent le caractére prioritaire des travaux de renouvellement et de dernisation des infrastructures municipales.
- La reconnaîssance que nous récherchons n'a rien du geste symbolique, elle suppose que les gouvernments, dont la capacité d'émprunt est elle aussi limitée, l'utilise en priorité au soutien de l'effort municipal.
- Duexièment, nous attendons des gouvernements qu'ils soutiènnent financièrement les administrations locales dans ce gigantesque projet par divers moyens à leur portée, c'est-a-dire des moyens financiers (contributions,

subventions, cautions financières, rémboursement d'emprûnt), et des moyens législatifs et réglèmentaires habilitant.

Il faudra que les gouvernements facilitent la tâche des adminstrations municipales, non seulement dans la phase de construction. Mais aussi après, dans la phase d'exploitation des reséaux renouvelés ou replacés.

Les gouvernements doivent réconnaître les administrations municipales comme les maîtres d'oeuvres les plus expérimentés et les plus habilés à mener ce programme.

ÇÇCela suppose que les gouvernements réspectent l'autonomie locale, les priorités d'éxécution et les échéanciėrs de réalisation définis par le consensus local des citoyens, tel qu'il s'exprime dans les décisions du conseil municipal.

The City of Montreal will support the Federation of Canadian Municipalities in its efforts to conclude an agreement on cost-sharing programs for the renewal of urban infrastructure.

EDUCATION, TRAINING AND RESEARCH NEEDS FOR URBAN INFRASTRUCTURE RENEWAL

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ABSTRACT

The preservation of our society's massive investment in urban infrastructure requires periodic maintenance and rehabilitation at the right time and in the right places. This paper suggests that while sufficient financing and political action are clear requisites for such infrastructure preservation and renewal, both the public and private sectors also have to have qualified people to implement the work.

Regarding the public sector, a Federation of Canadian Municipalities (FCM) study has shown the major problem areas to be roads, sewage collection, water distribution, bridges, water treatment, and sewage treatment. An operational framework for tackling the maintenance and renewal needs of these problem areas, or any other infrastructure component, has been proposed. The generically-based activities within this framework have been matched with the specific skills required to carry out the activities. These skills can only be acquired, however, by a combination of basic education plus subsequent training and experience.

The paper suggests that, while our current education programs do a very good job of providing the education fundamentals, the philosophy of how we do things requires some changes. For example, we need more emphasis on the application of design to renewal, rather than the traditional concentration on new designs. As well, we need well-documented case histories and well-organized continuing education that address the new demands placed on the civil engineering profession. These demands are as challenging, if not more so, in a technological and managerial sense as any past requirements for designing and building new facilities.

A number of key research needs associated with urban infrastructure renewal have been identified. These range from developing technologies for new design, materials, construction, and maintenance, to methodologies for modelling the deterioration of infrastructure renewal alternatives, and optimization procedures.

Finally, some prospects for the future are considered, such as the application of expert systems technology, and the development of specialized expertise in building renovation, pavement management, underground services rehabilitation, and others.

RESUME

Pour protéger nos investissements considérables dans les infrastructures ubraines, nous devons procéder, en temps et lileu, à l'entretien et au réaménagement de ces installations.

M. Haas et ses collègues sont d'avis que, bien qu'il est essentiel de prendre des dispositions financières et politiques suffisantes pour préserver et renouveler au besoin les infrastructures, il est tout aussi nécessaire d'avoir le personnel compétent pour exécuter ces travaux.

On a besoin de ces personnes dans le secteur public et dans le secteur privé. Pour ce qui est du secteur public, une étude effectuée par la Fédération canadienne des municipalités (FCM) a démontré que les principales sources de problèmes sont les routes, les réseaux de collecte d'égout et d'aqueduc, les ponts et les installations de traitement des eaux potables et usées.

Les auteurs proposent un cadre fonctionnel pour répondre aux besoins d'entretien et de renouvellement de ces réseaux ou de tout autre élément de l'infrastructure. Ils indiquent en outre les compétences requises pour exécuter les activités que suppose normalement ce cadre. Or ces compétences ne peuvent être acquises que par l'addition d'une formation spécialisée et d'expérience aux études usuelles. En effet, bien que les programmes d'enseignement actuels conviennent très bien pour assurer une éducation de base, il nous faut modifier la philosophie dictant notre façon de faire. Ainsi, nous devrons insister davantage sur la - reconception - c'est-à-dire l'adaptation et l'amélioration de la structure en place - plutôt que sur la production de nouveaux concepts comme il était coutume jusqu'ici. De même, nous avons besoin de dossiers pratiques bien documentés et d'une formation permanente bien organisée et axée sur les nouveaux besoins aux-quels la profession du génie civil doit répondre. Ces besoins sont à tout le moins aussi exigeants, au plan

technique et administratif, que les besoins exprimés jusqu'ici à l'égard de la conception et de la construction de nouvelles installations.

Les auteurs définissent un certain nombre des besoins de recherche primordiaux associés au renouvellement de l'infrastructure urbaine. Ces besoins vont de l'élaboration de nouveaux concepts, matériaux et techniques de construction et d'entretien au perfectionnement de méthodes de modelisation de la deterioration des structures de renouvellement possibles et à la mise au point de méthodes d'optimisation.

On examine enfin certaines solutions prometteuses, notamment l'emploi de systèmes experts et le perfectionnement de compétences spécialisées dans les domaines comme la rénovation de bâtiments, la gsion des chaussées et le réaménagement des services souterrains.

INTRODUCTION

Our society has a massive investment in its urban infrastructure. To preserve this investment, periodic maintenance and rehabilitation or renewal has to be carried out in the right places and at the right times. But strong evidence points to a significant deterioration of the infrastructure and a huge backlog of work to restore optimum conditions. In fact, the magnitude of this backlog has been estimated at $14 billion in a study carried out for the Federation of Canadian Municipalities (FCM)(1). According to Curtis et al. (2), current public works budgets will have to be increased by about 25% per year over a 10-year period to achieve recovery.

By far the greatest impediment to protecting and rehabilitating the infrastructure is lack of sufficient funding (la,3). Clearly the need is for dollars, but this in itself is insufficient. We also need the technology and the management to do the work as cost-effectively as possible, and this means having people with the right skills. In other words, we need people who have the education, training, and research skills appropriate to tackling the problems of urban infrastructure renewal.

The basic purpose of this paper is to identify the most important of these education, training, and research needs, and to provide some suggestions for improvements. More specifically, it is intended:

1. to define the major public and private sector components of the infrastructure and their key problems;
2. to relate these problems to education, training, and research needs so that we can assess how well we are currently meeting these needs; and
3. to develop recommendations for improvements and consider some prospects for the future.

To keep the scope of the paper manageable, it is limited mainly to the public sector, and to those components representing the major investment, and problems. As well, because civil engineering is involved to the largest degree in infrastructure renewal, it is the area given primary emphasis.

ROLE OF EDUCATION AND TRAINING IN URBAN INFRASTRUCTURE RENEWAL

The study carried out for FCM (1a) determined that lack of financing was the largest single impediment to achieving urban infrastructure renewal. Other factors were excessive time for public reviews and red tape, political inaction, and lack of staffing. These factors are summarized in Figure 1 as the key policy and political inputs. Figure 1 also shows the role of education, training,and research in terms of management and technical requirements inputs.

The intent of Figure 1 is to demonstrate that, while sufficient financing, political action, etc. are clear requisites for infrastructure renewal, it is also necessary to have cost-effective alternatives, as well as educated and trained people to implement those alternatives, if the benefits are to be fully realized.

MAJOR COMPONENTS OF THE URBAN INFRASTRUCTURE AND ASSOCIATED PROBLEMS

Urban infrastructure in the broadest sense incorporates social, political, economic, and physical facilities components. While all four are essential to our type of society, the physical facilities components represent the large dollar investment because they deteriorate with time and use.

Major Physical Components

If we are to identify the education, training, and research needs for tackling infrastructure renewal adequately, the major components of this physical part of the infrastructure and the key problems that exist first must be defined.

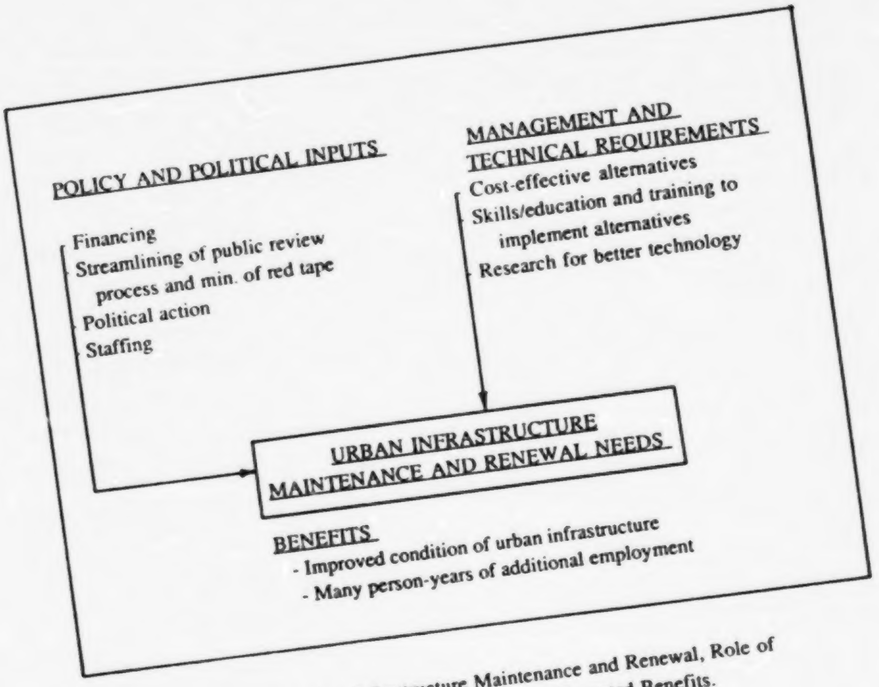
POLICY AND POLITICAL INPUTS
Financing
Streamlining of public review process and min. of red tape
Political action
Staffing
MANAGEMENT AND TECHNICAL REQUIREMENTS
Cost-effective alternatives
Skills/education and training to implement alternatives
Research for better technology
URBAN INFRASTRUCTURE MAINTENANCE AND RENEWAL NEEDS
BENEFITS
- Improved condition of urban infrastructure
- Many person-years of additional employment

Figure 1. Inputs to Urban Infrastructure Maintenance and Renewal, Role of Education, Training and Research, and Expected Benefits.

Figure 2 provides a listing of the public- and private-sector components (la,4). The private-sector components are included only for purposes of comprehensiveness. While private-sector needs for renewal are driven by market forces, the consultants, contractors, fabricators, and materials suppliers involved also must have people with the proper education and training. The technological and management challenges are no less demanding for the private sector than for the public sector.

URBAN PHYSICAL INFRASTRUCTURE

PUBLIC SECTOR

Transport (roads and streets, bridges, walks, parking facilities, transit, traffic control)

Water (treatment plants, pipes, pumping stations, reservoirs)

Sanitary (sewer lines, treatment plants, manholes, waste disposal sites)

Storm sewers (runoff systems)

Public buildings (offices, warehouses, plants, public housing)

Service facilities and equipment

Health care and social services

Fire protection

Parks and recreation (swimming pools, community centers, ice rinks)

Libraries and museums

Security and crime prevention (police stations, jails, equipment)

Education facilities (schools, equipment)

PRIVATE SECTOR

Power and energy supply (plants, lines, cables, stations, fuel storage)

Communication (telephone lines/cables, TV and radio stations, newspaper plants)

Housing (single and multiple)

Commercial, business and industrial buildings and parking facilities

Entertainment (movies, restaurants, sports, facilities, night clubs, etc.)

Service (service stations, taxi fleets, for-hire, trucking)

Religious (churches)

Retail (stores and shops, food markets)

Figure 2. Some of the major public and private sector components of the urban physical infrastructure; After (la,4)

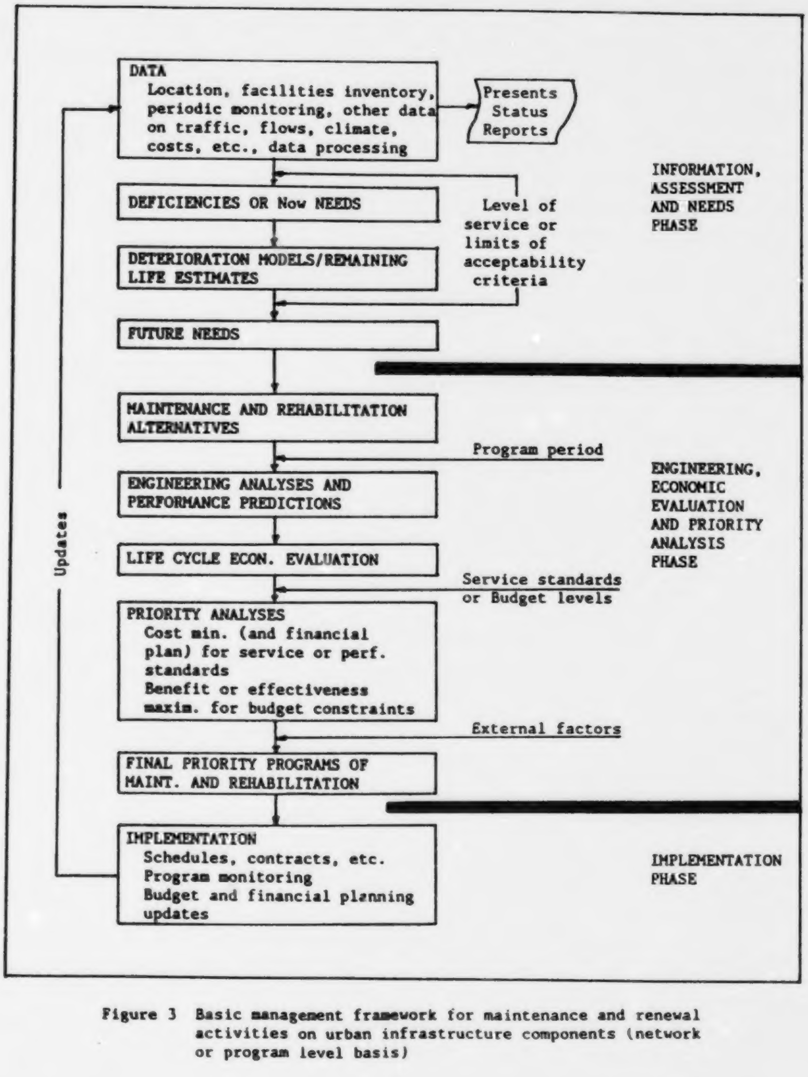
DATA
Location, facilities inventory, periodic monitoring, other data on traffic, flows, climate, costs, etc., data processing
Presents Status Reports
DEFICIENCIES OR Now NEEDS
Level of service or limits of acceptability criteria
DETERIORATION MODELS/REMAINING LIFE ESTIMATES
FUTURE NEEDS
INFORMATION, ASSESSMENT AND NEEDS PHASE
MAINTENANCE AND REHABILITATION ALTERNATIVES
Program period
ENGINEERING ANALYSES AND PERFORMANCE PREDICTIONS
LIFE CYCLE ECON. EVALUATION
Service standards or Budget levels
PRIORITY ANALYSES
Cost min. (and financial plan) for service or perf. standards
Benefit or effectiveness maxim. for budget constraints
External factors
FINAL PRIORITY PROGRAMS OF MAINT. AND REHABILITATION
ENGINEERING, ECONOMIC EVALUATION AND PRIORITY ANALYSIS PHASE
IMPLEMENTATION
Schedules, contracts, etc.
Program monitoring
Budget and financial planning updates
IMPLEMENTATION PHASE
Updates

Figure 3 Basic management framework for maintenance and renewal activities on urban infrastructure components (network or program level basis)

Major Problem Areas

The study carried out for FCM in 1984 (la) indicates that the major problem areas of the infrastructure were roads, sewage collection, water distribution, bridges, water treatment and sewage treatment, in order of priority. It also indicates that 41% of the total costs to bring the infrastructure to an acceptable level would have to be spent on roads, primarily the maintenance and rehabilitation of pavements.

This relatively large need of the road component was the primary reason for the development of a comprehensive pavement process initiated in Canada (5,6). It illustrates that technology and management can respond to a need. It is also noteworthy that research in the area has led to many technological improvements and that a substantial number of municipal and provincial/state authorities have implemented or are implementing pavement management systems (7). The basic framework for pavement management has been well developed and can provide guidance to other infrastructure components such as bridges (8) and underground services (9). Moreover, it provides a very useful context for assessing education and training needs for all aspects of infrastructure renewal.

A FRAMEWORK OF ACTIVITIES FOR IDENTIFYING EDUCATION AND TRAINING NEEDS

An operational framework for the network and project levels of management has been well established for the road component of urban infrastructure renewal. Recent efforts (10) suggest that the basic framework is equally suitable for the underground services components.

The Basic Framework

If such a basic framework can have applicability to a wide range of infrastructure components, and if the key generic activities within this framework can be identified, then a basis exists also for identifying the skills or education and training needs to carry out those activities.

Figure 3 provides the basic framework for the network or program level of management. It is comprehensive and incorporates the key steps in carrying out infrastructure maintenance and renewal, starting from the initial acquisition of data, to the engineering analysis and economic evaluation of alternatives, to the development of priority programs of work and, finally, to actually implementing those programs. A corresponding framework for the project level of management could be developed.

Major Activities Within the Management Framework

The major activities within the framework of Figure 3, on a generic basis and grouped into blocks, are identified in Table 1 for both network and project levels of management. A generic labelling of these activities is for applicable to all infrastructure components. For any particular component, such as roads, the facilities inventory activity of the network data block of Table 1 would include, for example, number of lanes, lane widths, type of pavement, etc. Or, as another example, it would include for the sewage collection component such items as type of pipe, slope, manholes, etc.

Skills Needed to Carry Out Activities

The framework of Figure 3, and the more detailed activity listing of Table 1, provide a means for identifying in turn the education and training needs required for each activity. At this stage, however, it is more appropriate to talk first about the skills associated with these activities and then, subsequently, to consider the education and training required to develop those skills. Consequently, Table 2 attempts to match the basic activities of Table 1 with some of the skills required. Only two aggregated infrastructure components, roads and bridges, and water and sewer, have been used in Table 2. The skills required for the other infrastructure components could be identified similarly by the type of matrix shown in Table 2. As well, only the desired presence of each skill for the example aggregated infrastructure components (R for roads and bridges and W for water and sewer) is shown. This could be further subdivided for each activity-skill combination in terms of, say, senior administrative, middle management and operational level involvement.

The presence or absence of R's and W's in the various activity-skill combinations of Table 2 is not intended to be conclusive, nor is the listing and labelling of skills per se. Obviously, it is somewhat arbitrary; additional or more detailed skills undoubtedly could be identified. Nevertheless, Table 3 does suggest the following:

1. An extensive set of managerial/administrative, technical, and other special skills is required to address urban infrastructure maintenance and renewal in a comprehensive way.
2. The fundamentals for many of these skills can be acquired in the basic university and technical college environment. A number of the other skills, however, must be acquired through additional education, on-the-job training, and experience.
3. Very few, if any, individuals would have the comprehensive set of skills, and the depth within those skills, for any given infrastructure component. In addition, only the larger municipalities or consulting

TABLE 1
MAJOR GENERICALLY BASED ACTIVITIES ASSOCIATED WITH THE MAINTENANCE AND RENEWAL OF ANY URBAN INFRASTRUCTURE COMPONENT

BASIC BLOCKS OF ACTIVITIES	NETWORK OR PROGRAM LEVEL OF MANAGEMENT	PROJECT MANAGEMENT LEVEL
A. DATA	• Locational reference system • Facilities inventory • Field monitoring data on condition, flows, traffic, climate, etc. plus other data on costs, etc. • Data processing • Present status reports (graphical and tabular)	• Detailed site data (structural, materials, soils, unit costs, etc.) • Subdivision into project components, subsections, etc. • Data processing
B. CRITERIA	• Minimum level of service, structural adequacy, capacity, safety, etc. • Maximum user costs, maint. costs • Maximum program costs/ budget • Selection criteria (effectiveness maximization, benefit, max., etc.)	• Maximum as-built variance from spec., min. structural adequacy or capacity, etc. • Maximum project costs • Minimum interruptions (service, flows, etc.) • Selection criteria (i.e., min. life-cycle cost)
C. ANALYSES	• Network needs (now) • Deterioration predictions and future needs • Maint. and rehab. alternatives • Eng. analysis and perf. predictions • Life-cycle economic evaluation • Priority analyses • Evaluation of alternative funding levels	• Within-project alternatives • Testing (materials, struct. components, etc.) and design analyses (behaviour, deterioration rates, etc.) • Quantity estimates • Life-cycle cost analyses
D. SELECTION	• Final priority program of capital projects • Final maintenance program and budget	• Best within-project alternative • Maintenance treatments for individual sections, links, lines, etc.
E. IMPLEMENTATION	• Contracts schedule, tendering, awards • Maintenance schedule Program monitoring • Budget and financial planning updates	• Constr. activities, contract control (quality assurance, etc.) and as-built records • Maint. activities, reporting and records (maint. management) • Budget and schedule updates

> firms would likely approach such a comprehensive set of skills within their own personnel resources. This suggests, in turn, that smaller municipalities should have good access to or information on what expertise, methodology, manuals, programs, etc. are available; and equally important: access to or information on how to assess the limitations and applicability to their particular situations and requirements.

The logical question arising from the type of requirements shown in Table 3 is to what degree or how well arethese skills (in both quality and quantity) are being developed by our education and training programs?

HOW WELL ARE WE MEETING EDUCATION AND TRAINING NEEDS?

The education and training needed for urban infrastructure renewal comes from the following sources: a) university, b) technical college, and c) on-the-job training. Of the first source, the major requirement would be for civil engineering students to acquire knowledge in business administration, mathematics, science, etc.

Education Fundamentals vs Education and Training Needed to Tackle Renewal

If one examines any civil engineering program in the country, it seems that the education provided contains all the fundamentals needed, such as mathematics, physics, chemistry, computer science, statics and dynamics, fluid mechanics, properties of materials, probability and statistics, engineering economics, and structural analysis. As well, it contains the fundamentals of such applied subjects as transport engineering, structural design, geotechnical engineering, hydrology and hydraulics, water quality engineering, and wastewater treatment.

A lot of additional technology and experience, however, is needed to bridge the gap between knowing these fundamentals and having the skills to actually work on infrastructure renewal. This acquisition of technology and experience must come primarily from: a) on-the-job training, b) further study, and c) specialty seminars, workshops, short courses, etc. In some cases, where more in-depth knowledge is required, formal post-graduate study is useful. One such example is pavement engineering and management, which is addressed only in an introductory sense in undergraduate programs. As well, the managerial or administrative skills needed must come primarily after graduation.

BASIC ACTIVITIES		NON-TECHNICAL SKILLS						BASIC SKILLS				
		FINANCIAL PLANNING	PUBLIC POLICY	BUSINESS ADMIN.	PERSONNEL MANAGEMENT	ENGINEERING LAW	PUBLIC RELATIONS	COMPUTING	DATA BASE DESIGN & MANAGEMENT	PROBABILITY & STATISTICS	MATHEMATICAL MODELLING	ENGINEERING ECONOMICS
NETWORK LEVEL												
DATA	Locational reference system							RW	RW			
	Facilities inventory				RW			RW	RW			
	Field monitoring and other data				RW			RW	RW			
	Data processing				RW			RW	RW	RW		
	Present status reporting							RW	RW	RW		
CRITERIA	Min. levels of service, etc.		RW			RW						
	Max. user costs, maint. costs		RW									
	Max. program costs/budget	RW	RW	RW								
	Selection criteria (i.e., benefit max.)		RW									
ANALYSES	Network needs (now)							RW	RW			
	Deter. predictions and future needs							RW	RW	RW	RW	
	Maint. and rehab. alternatives											
	Eng. anal. and perf. predictions							RW	RW	RW	RW	
	Life-cycle econ. eval.							RW				RW
	Priority analyses							RW			RW	RW
	Eval. of alternative funding levels			RW				RW				RW
SELECTION	Final (capital) priority program	RW	RW	RW								
	Final maint. program and budget	RW	RW	RW								
IMPLEMENTATION	Contract schedule, awards	RW		RW				RW				
	Maintenance schedule							RW				
	Program monitoring			RW	RW			RW				
	Budget and financial planning updates	RW		RW				RW				
PROJECT LEVEL												
DATA	Detailed site and other data				RW			RW	RW	RW		
	Subdivision of project							RW	RW	RW		
	Data processing							RW	RW	RW		
CRITERIA	Specific.; min. or max. standards									RW		RW
	Max. project costs	RW	RW									RW
	Min. interruptions to service		RW				RW					
	Selection criteria (i.e., min. costs)		RW									
ANALYSES	Within-project alternatives											
	Testing and design analyses											
	Quality estimates							RW				
	Life-cycle cost analyses							RW				RW
SELECTION	Best within-project alternative											RW
	Maint. treatments for sections, lines											
IMPLEMENTATION	Constr. activities: control; records				RW	RW	RW	RW	RW	RW		
	Maint. activities and records				RW			RW	RW	RW		
	Budget and schedule updates	RW		RW				RW				

TECHNICAL AND SPECIAL SKILLS																		REQ.
GEOTECHNICAL OR GEOLOGY	BUILDING MATERIALS	CONSTRUCTION MATERIALS	SPECIAL MATERIALS	MATERIALS TESTING	FIELD TESTING & INSTRUMENT.	FLOW ANALYSIS (PIPES & NETWORKS)	HYDROLOGY AND HYDRAULICS	WATER QUALITY & TREATMENT	WASTEWATER TREATMENT	TRAFFIC OPERATIONS & ANALYSIS	PAVEMENT ENG. & MANAGEMENT	BRIDGE ENG. & MANAGEMENT	STRUCTURAL STEEL DESIGN	STRUCTURAL CONCRETE DESIGN	CONSTR. ENG. & MANAGEMENT	MAINT. ENG. & MANAGEMENT		COMMON SENSE
R										R	R	R						RW
																		RW
				RW	RW													RW
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		RW	RW			W	W	W	W	R	R	R	R	R				RW
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As an example of the difference between a fundamental that can be acquired as part of an educational program, and a skill that is the result of experience and training, consider the area of bridge rehabilitation. Haber (11) has described a typical situation; namely the Pulaski Skyway in New Jersey (which consists of a series of stringer, girder, and truss spans), where current specifications and design methodology would require a prohibitively costly reinforcement or replacement of the outside stringers. However, after careful evaluation and judgment based on experience, as well as a working stress analysis with of the loads to be carried on the outside stringers, it was decided that a much less expensive rehabilitation was possible. The key point here is that the basic education was not deficient in terms of design and analytical skills. Rather, it needed to be supplemented by experience, the acquisition of further knowledge of the technology of rehabilitation and re-analysis skills. Moreover, as recommended by Haber (11), good, case-history documentation of such situations would be very valuable in supplementing the basic education to foster the skills required to actually tackle the renewal job.

Adequacy of Current Education Programs

Current education programs provide the fundamentals needed, as previously suggested. It would be a mistake to expect them also to provide the specific, applied skills required to tackle infrastructure renewal. One reason is that the universities have a longer-term role of providing a fundamental education rather than immediate training. Another reason is that it is very difficult to cover even a minimum set of these fundamentals in the time available. If too much of that time is taken up with specific training on today's problems, then the longer-term benefits of having fundamental problem-solving skills will suffer.

Thus, changes in current educational programs or curricula are not needed. What is needed are changes in the philosophy of how we do things to reflect the fact that the civil engineer is increasingly involved in managing the renewal of existing infrastructure rather than planning, designing, and building additions or new infrastructure. This new role is every bit as challenging, if not more so from a technical standpoint, as the more traditional role. Our educational programs must respond by:

- incorporating more examples of rehabilitation or renewal in courses and texts;
- putting more emphasis on "re-analysis" methodology used in design;
- developing better methodologies for evaluating and monitoring existing structures, facilities and processes;
- recognizing the vast expansion of new or modified materials becoming available to civil engineering; and

- developing new or improved construction and operational methods and processes for renewal.

Hanson (12) has stated that, "Most of our engineering colleges do an excellent job of educating their students for design of new facilities .... most employers are reasonably satisfied by the content of the education provided." He goes on to say, however, that what cannot be taught effectively is performance experience and that there are a few philosophical concepts that colleges can use to upgrade their graduates' abilities in solving the complex problems created by the need to rebuild rather than build a new. These include the following:

- use of real behavior of in-service structures or other public facilities or comparison with theories and laboratory studies, including extremes of severe deterioration, damage, or failure;
- use of hands-on experience with damaged materials and systems, closely coupled with theories and computer model or simulation studies; and
- experimental studies on repair, rehabilitation, and strengthening technologies.

Turkstra (13) also has put forward a strong argument for a change in the philosophy of civil engineering education. He suggests that the comparative success of such other disciplines as business and law is due largely to their ability to use soft sciences (i.e., psychology, organizational theory, sociology, etc.) and case situations effectively in preparing their students to tackle the complex problems of today's society. He also suggests that engineering must find a way to couple a scientifically-oriented education with the development of abilities to cope with poorly-defined situations or problems. One way to do this is through formal case studies that incorporate both the technical questions and all the legal, economic, political, and social factors that usually occur. Urban infrastructure renewal provides an ideal, and perhaps necessary, environment for accomplishing this objective.

The foregoing discussion also requires questionning how far the responsibility of the university as a whole should go in demanding that its engineering faculty and civil engineering department provide the package of skills required for tackling infrastructure renewal. An engineer leaves the undergraduate program with many of the basic tools: mathematics, physical and natural sciences. However, the skills to use these technical tools are only a part of the total package of skills which must be acquired. What is the role of the university in this total process? For the undergraduate engineer, it should offer the basic tools, and the existing curricula are reasonably adequate in this regard. However, to "engineer" the vast infrastructure renewal efforts needed during the next decade or more, the universities and their faculties should assume some additional responsibilities, including the following:

- identifying those areas where the basic skills require major upgrading or extension, and the mechanisms for accomplishing those extensions (i.e., graduate studies, specialty workshops, etc.);
- re-examining the philosophy of existing programs, particularly regarding the development of a formalized set of case studies in various areas. These case studies should be set up as organized professional archives, prepared with the assistance of and available to the profession;
- upgrading textbooks and course notes to provide examples of re-design, as well as those dealing with the provision of new works;
- encouraging faculty to obtain experience with renewal and rehabilitation problems in the various infrastructure components;
- encouraging research on infrastructure problems and the development of improved technologies;
- communicating the fact that the professional environment for civil engineers is increasingly becoming one of engineering and managing renewal. It is also necessary to emphasize that this offers challenges and responsibilities as great as, or greater than, dealing with the engineering of new works;
- assisting governments, industry, and the profession in developing more formalized estimates of the number of engineers and associated skills required over the next decade or more;
- organizing, in cooperation with the profession, industry and governments, professional seminars, workshops, courses, etc. dealing with infrastructure renewal problems and technology; and
- establishing formal links, wherever possible, with practising experts in the various areas of urban infrastructure (i.e., adjunct professorships).

Issues Concerning Quality and Number

The technical quality of the people and of the technology needed to tackle infrastructure renewal is difficult to define, yet very important. Obviously, the public is most effectively served by having the best qualified individuals for the problem being tackled. But what constitutes "best qualified"? The field of urban infrastructure renewal involves a rapidly emerging technology, ranging from new design and construction techniques, to new materials, to new methods of surveillance and maintenance. For example, a new type of sewer lining material may be developed and installed with the best expertise and technology available today. But, if it deteriorates to an unacceptable level of serviceability and has to be replaced in 5 years then its use would not have been very cost-effective. It is important, therefore, that we not only put effort into developing new technology for urban infrastructure renewal, but also in carrying out rigorous reviews of the performance of that technology and the systems in service, plus careful documentation, so that the quality issue is given proper attention.

Assessment of the number of individuals and the extent of skills needed for urban infrastructure renewal during the next decade also requires consideration. The "Work, Work, Work" study carried out for FCM (lc) estimated the amount of employment that could be generated if funds for the $14 billion backlog of work became available. Associated studies for estimating the supply and demand of the specialized expertise required (i.e., civil engineers) have not yet been carried out. Previous work has shown that comprehensive studies of this sort, such as in the area of technical manpower for transportation (14) can be very useful for future planning. However, some preliminary estimates can be made regarding the orders of magnitude of engineers and technicians required for various levels of funding.

For example, taking the extremes of a most optimistic and very pessimistic scenarios, which are respectively the full $14 billion over 10 years and only, say, $0.25 billion per year, and assuming that each $1 million of such capital spending will require about 1/2 to 1 civil engineering position plus about 1 to 3 technicians, suggests the following:

Level of Funding per Year	Additional Employment Opprotunities	
	Engineers	Technicians
$1.4 billion per year	700 to 1,400	700 to 4,200
$0.25 billion per year	125 to 250	125 to 750

As can be seen, even under a pessimistic scenario of only limited funding for urban infrastructure renewal, several hundred additional civil engineers and technicians will be required on a continuing basis. Since there is no ready supply of people with the necessary training and skills available, a major effort will be required to provide the manpower.

In essence, while the issues of magnitude and types of renewal work needed, financing, spending priorities, and political action receive a great deal of attention in many forums and publications (15), the issues of quality and supply of skilled manpower required are also very important if the funds available are to be spent cost-effectively.

Role of Continuing Education

It was suggested earlier that: a) new graduates will not have all the skills required for infrastructure renewal, and b) there will be a shortfall of trained engineers and technicians if additional funding is provided for the necessary work. Therefore, it is very important that the existing information and expertise on infrastructure renewal be made available to the fullest extent possible.

Universities can take a lead role by organizing and holding seminars, workshops, short courses, and formal courses. These should be undertaken with full cooperation and assistance from engineers and managers, consultants and other groups knowledgeable about infrastructure renewal. An example of such support and cooperation in one area of infrastructure is the 6-week, graduate-level course on pavement management (for full university credit) developed at the University of Texas at Austin and financed by the U.S. Department of Transportation (16). This course has now been run for about 150 engineers from the U.S., Canada, and abroad. It should have a major impact in developing new or additional skills and, in turn, in achieving more cost-effective programs of maintenance and rehabilitation.

Because sufficient numbers of experienced people do not exist in most areas of infrastructure renewal, the expertise has to be shared across the country. This might include cross-Canada "tours" by groups of experts. It requires a substantial effort. It also requires that "customers" for such seminars be available, which means that public and private agencies must be willing to allow the time and funds for their staff to attend. Instructional material and case applications developed for such seminars also can be incorporated with undergraduate instruction wherever possible.

Impediments to the Education and Training Required

There are several major impediments to achieving the level of education and training required for urban infrastructure renewal. These include the following:

The attraction or "glamour" attached to new design and construction, such as the CN Tower or the Dome in Toronto. It is common, when pointing out major achievements in civil engineering, to illustrate them with such high-profile projects. As well, the fees for designing new facilities are usually higher. There is a real need to communicate the technical, economic and social challenge posed by preservation of the massive public investment in infrastructure.

Declining enrolments in civil engineering. Since 1980, civil engineering enrolments have declined at most Canadian universities for reasons that include: a) a slowdown in the economy, with its usual immediate effect on civil engineering employment; b) the attractiveness of such"high tech" areas such as electrical and computer engineering with an attendant lack of recognition that civil engineers are probably as active in computer use and applications in their profession as any other branch of engineering, if not more so; c) a lack of appreciation of the extremely cyclic nature of civil engineering supply and demand and the fact that demand almost certainly will continue to increase in the late 1980s. The profession has not done a good selling job on the overall challenges of infrastructure renewal and on the specific technical challenges associated with developing new methods of design analysis, materials, construction, operations, applications of computers, etc. As well, the fact that substantial jobs will be generated by these challenges has not been communicated.

Availability of people who have the expertise, and time to communicate it. Infrastructure renewal involves a rapidly growing technology. There are not many experts in the various areas. Moreover, they are often too busy to document and communicate their developments properly. Preparation of case material is time-consuming. More recognition and perhaps some sort of renumeration for this very important function is required on the part of the profession.

Lack of reports on failures or unsatisfactory performance. A great deal can be learned from a failure. The geotechnical area of civil engineering has recognized, for example, the value of formal reports on foundation or slope failures, but, this is an exception rather than the rule. People generally like to documentsuccesses. Moreover, there are often insurance and legal reasons why failures are not reported. The profession should do more to encourage such documentation whenever technically-desirable and legally-possible.

Lack of experience in infrastructure renewal in educational institutions. Most faculty at Canadian universities have obtained their experience with planning, designing, and constructing new facilities. Because infrastructure renewal is such a " new" area itself, few faculty members have had the opportunity to acquire much practical knowledge in this area. Moreover, the textbooks generally contain examples associated with new facilities. There is a real need for Canadian university faculty to advance their state of knowledge on infrastructure renewal, to gain practical experience. This can be done through specialty consulting and off-campus leaves for assignments with private industry or municipal authorities, to address more research problems in this area, and to develop instructional material or examples of problems which use an infrastructure renewal context to illustrate fundamentals.

RESEARCH NEEDS

A NSF-ASCE Workshop in 1984 directly addressed infrastructure research needs (15). Among the key conclusions of that workshop are the following:

- research can make a major contribution to solving the nation's infrastructure problems;
- an appropriate mix of short-, intermediate- and long-range research programs is needed;
- the effective application of new, emerging technologies to resolve infrastructure problems requires a well thought-out research effort;
- adequate, long-term and stable financing is an essential ingredient to successful research programs;
- high-technology research is accompanied by risk; and
- better ways of disseminating and utilizing research results are needed.

At present, the actual level of research effort which addresses infrastructure problems is relatively low. Of some 80 to 90 research areas in civil engineering at the University of Waterloo, for example, only about 10% are directly concerned with urban infrastructure problems, another 10% are peripherally concerned and the remaining 80% range from only indirectly associated to quite separate (17). It is likely that a similar situation exists for other agencies that carry out a significant amount of research in Canada, such as provincial and federal ministries.

A notable exception to the low level of research on infrastructure problems is the 5-year, $150 million Strategic Highway Research Program (SHRP) in the United States, and it's Canadian counterpart (C.SHRP) which currently are underway (18). While not all areas of this program are concerned directly with infrastructure, some components, such as The Long Term Pavement Performance Monitoring, will have a major impact on developing a better infrastructure renewal technology. It would be highly desirable if a similar research plan and program could be developed for other areas of urban infrastructure renewal.

It is not possible in this paper to develop a comprehensive set of short-, medium-, and long-term research needs, and to suggest priorities, schedules, and the levels of funding required. However, preliminary lists applicable to highways, streets, and bridges and to water supply, wastewater, and stormwater can be developed from the Proceedings of the ASCE Workshop (15), previous references quoted, plus others, especially (19,20) and the authors' own experiences and perceptions. These preliminary lists are contained in Tables 3 and 4.

Tables 3 and 4 also contain suggested priority levels for the research needs listed, as well as the estimated prospects for short-, medium-, and long-term payoffs on the research. These are necessarily quite subjective and arbitrary, different people might arrive at different conclusions.

TABLE 3

RESEARCH NEEDS FOR REHABILITATION OF HIGHWAYS, STREETS AND BRIDGES

Research Needs by Area, With Specific Examples	Suggested Priority Levels*	Prospects for Payoff**
1. Development of technology for measuring and evaluating existing physical condition and performance		
- automated, high speed, reliable, understandable and consistent procedures and equipment	H	M
- manageable and useable data bases	H	S
2. Predictive methodology for rates of deterioration or remaining service lives		
- models for existing facilities, and after rehabilitation or maintenance	H	M
- effects of environmental and physical conditions, quality and types of materials, traffic loads and tire types, sizes and pressures	H	M and L
- undersanding deterioration mechanisms	I	M and L
- long term monitoring procedures	I	L
3. Rehabilitation and repair methods		
- alternatives, and techniques of application	I	S and M
- developing and assessing new materials and procedures	H	M and L
- adequacy of existing codes and standards	H	M and L
- user costs and public safety assessment	I	S and M
- equipment improvements	I	M and L
- innovations in methods	I	M and L
4. Management procedures		
- methods for establishing life-cycle benefits and costs	I	M
- optimization and near-optimization methods	I	S and M
- effects of alternative funding levels	I	S and M
- coordination of pavement, bridge and maintenance management	I	L
- resource allocation procedures and evaluation	I	M
- incorporation of political, public policy and social impact considerations on decision making	I	L
- establishment of systematic, case study documentation	H	M and L
- needs for and effects of automation	I	M
- communications needs and technology	I	M and L
- application of expert systems technology	I	M and L
- improvements in traffic operations methods	I	S

* (H) - High (I) - Intermediate (L) - Low

** (S) - Short (M) - Medium (L) - Long Term

TABLE 4

RESEARCH NEEDS FOR REHABILITATION OF WATER SUPPLY,
WASTEWATER AND STORMWATER SYSTEMS

Research Needs by Area, With Specific Examples	Suggested Priority Levels*	Type of Possible Payoff**
1. Techniques for assessing condition and performance of systems		
- in-situ measurement techniques for leaks, cracks, wall conditions, soil conditions, flows, etc.	H	S
- diagnoses of localized failures	I	M
- causes of increased pipe wall resistance and other deterioration mechanisms	I	M to L
- data bases, cross referenced with other infr. data bases	H	M to L
- combined condition indices for overall assessment	L	M
2. Performance modelling		
- predictive models for rates of deterioration and remaining service lives of existing systems	H	M
- models for predicting performance of new relining or repair materials and techniques	H	M
- comparisons between flow analysis modelling (design) and actual flows	I	S
- effects of industrial wastes on pipes		
- effects of different soils on pipes		
3. Rehabilitation and repair methods		
- development of better preventive maintenance methods	I	S
- methods for evaluating new materials and processes	H	M to L
- criteria for pipe wall cleaning and/or relining	I	S to M
- adequacy of existing codes and standards	I	M
4. More effective management and integration of technology		
- criteria for repair and rehabilitation needs	I	S
- comparative cost-effectiveness evaluation (life-cycle basis) of repairs vs. rehab. vs. reconstruction	H	M
- network optimization models/priority programming	H	M
- better operations management procedures	I	S
- systematic and efficient incorp. of new technology	I	S,M and L
- systematic case-study documentation	H	M to L
- applications of expert systems technology	I	M to L

* (H) - High (I) - Intermediate (L) - Low

** (S) - Short (M) - Medium (L) - Long term

In summary, the engineering community is responsible for the implementation of decisions on infrastructure renewal. To do this as efficiently as possible requires continuing innovation and the best possible use of available technology. Research is essential to realizing these innovations and constantly improving the cost effectiveness of renewal.

PROSPECTS FOR THE FUTURE

The available data on the condition of urban infrastructure suggest that a major investment in renewal is essential. There is a limit or minimum level of service beyond which society will not accept further deterioration. Unfortunately, if such minimum acceptable levels are allowed, the additional funds required to restore most infrastructure components to good condition amount to much more than what would have been needed earlier to protect the investment. For example, Sheflin (22) has shown that if a pavement is allowed to deteriorate to a minimum acceptable level of serviceability, it will cost 4 to 5 times more to rehabilitate would be needed 12% earlier in its service life to achieve the same result.

Consequently, the development of sound engineering approaches to solving the problem of infrastructure renewal, for any level of deterioration are imperative. This requires the effective use of available technology, development of specialized expertise and skills, and application of automation in all major activity areas.

The prospects for responding to these challenges are excellent, based on the extensive track record of civil engineering. In fact, examples already exist to suggest optimism for the future -- provided, of course, that the necessary financing and political action is forthcoming. These examples include the following:

Application of expert systems technology. Fenves (23) has suggested that artificial intelligence-based methods represent a radically new and very powerful problem-solving strategy for infrastructure evaluation and repair. These methods allow the knowledge base of experts to be "captured" and used, together with quantitative information, to arrive at solutions to problems. Fenves has further suggested that the emergence of expert systems will introduce changes at least as far-reaching as the entire computer revolution to date.

Specialty consultants. The depth of expertise and knowledge needed to deal with the complexity of urban infrastructure renewal problems has led to the establishment of a number of specialty consulting firms. A good example is the field of pavement management, where several high-technology consulting firms have been formed in Canada and the U.S. during the past decade. Similar examples can be cited for the area of undergound services and building renovation. The prospects are good that more specialized firms of this sort will be developed and that the educational and training process will respond to the need.

Specialty contractors and materials. The formation of specialty contractors and the development of specialty materials in response to a growing demand for infrastructure renewal is a natural response to market conditions. This involves such areas as building renovation, water and sewer rehabilitation, restoration of parks and recreation facilities, and bridge repairs. On the materials side, it involves expoxy coatings for both sewer rehabilitation and reinforcing steel, polymer lining materials and chemical grouting for sewer lines, and many others.

Automation of evaluation, analysis and construction methods. This is also a rapidly growing area and can be illustrated by such examples as the application of automated, high speed image acquisition and analysis methods for the evaluation of pavement surface condition (24), or the application of robotics to construction (25). Prospects for continuing, major advancements and applications in this area are also excellent.

SUMMARY AND CONCLUSIONS

If decisions regarding the financing and political action on urban infrastructure renewal are to be implemented in a cost-effective way, people with a range of special skills are needed as is the research to solve a range of problems. The major points and conclusions of the paper can be summarized as follows:

- skilled and trained people are a requisite to evaluating urban infrastructure conditions properly, identifying the feasible alternatives, conducting the necessary technical analyses for selecting the best option, and implementing the work;
- an operational framework for all the activities associated with infrastructure renewal, for both the overall program level and the specific project level of management has been defined. This framework is based on a generic set of activities and is applicable to any infrastructure component;
- the non-technical, basic, and special skills required to carry out these activities have been identified. While the fundamentals for these skills are provided in the academic programs of educational institutions, additional technology and experience has to be acquired to develop such skills. This comes primarily from on-the-job training, further study, and specialty seminars or workshops. It would be a mistake to expect the academic programs to

provide these specific applied skills because the universities have the longer-term role of providing a fundamental education to students rather than immediate training;

- while changes in educational programs are not needed, there are some changes in philosophy that would be worthwhile. These include the use of more examples of renewal in courses and texts, more emphasis on "re-analysis" techniques in design, development of better methodologies for monitoring and evaluating existing facilities and processes, more recognition of the rapid growth in new and modified materials technology, and the development of new or improved construction and operations methods. Furthermore, the development of well-documented case histories of renewal, encouragement of faculty to gain experience with rehabilitation problems, more extensive opportunities in continuing education in the form of seminars and workshops on renewal as well as graduate courses, establishment of more formal links between the universities and practising experts, and the encouragement of research or renewal problems would be very desirable;
- the question of the number of skilled engineers and technicians that would be required for urban infrastructure renewal, should any substantive funding become available, has not been addressed adequately. For example, even a very modest amount of $250 million annually would require in the order of 200 additional engineers and 400 technicians;
- there are several impediments to achieving the education and training required to provide a sufficient number of skilled engineers and technicians;
- research can make a major contribution to solving the nation's infrastructure renewal problems. For many infrastructure components, research needs include the following:
  a) development of technology for measuring and assessing existing physical conditions and performance;
  b) development of predictive methods for rates of deterioration or remaining service lives of both existing facilities and renewal alternatives;
  c) rehabilitation and repair methods and materials;
  d) management procedures dealing with such items as estimating life-cycle costs and benefits, optimization, effects of different funding levels, resources allocation procedures, incorporation of public policy and social impact considerations on decision making, and communications techniques;
- there is a minimum level of service beyond which society will not accept further deterioration. The development of sound engineering approaches to solving the problems of renewal, up to and including such minimum acceptable levels, is imperative. It will require the effective use of available technology,

the development of specialized expertise and skills and the application of automation;

- the prospects for responding to these development challenges are excellent, based on the extensive track record of civil engineering. Current examples of developments already underway include the following:
  a) applications of expert systems technology to a number of areas of infrastructure repair and renewal;
  b) the establishment of specialty consultants with in-depth expertise in such infrastructure areas as pavement management, building renovation, underground services management, and others;
  c) specialty contractors and materials in such areas as water and sewer line rehabilitation and bridge repairs.
  d) automation of evaluation, analysis and construction methods, including applications of image analysis technology, and construction robotics.

Education, training and research can have a profound influence on how well and how fast these future prospects are realized.

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